5

Traditional and recent developments in yoghurt production and related products

5.1 Introduction

The accepted homeland of yoghurt is the Balkan peninsula and the Middle East region. To the communities living in those parts of the world, this type of fermented milk product is identified and known as natural/plain unsweetened yoghurt. The per capita annual consumption is high and in Bulgaria, in particular, is 31.5 kg head^{-1} year^{-1} (IDF, 1977). It is evident, therefore, that yoghurt plays an important role in the diets of these communities. Furthermore, it is customary for yoghurt to be consumed not only as a refreshing drink, but also as a main ingredient during the preparation of a wide variety of dishes including salads and soups; such food habits and their ensuing consumer attitudes may well be a contributory factor to the high annual consumption. Incidentally, recipes for yoghurt dishes are increasingly being included in cookery books, for example, Norris (1972), Hunter (1973), Nilson (1973), Orga (1975), Black (1977), Kay (1978), Newman (1978), Lanigan (1978), Stuart (1979), Hinfey (1980), Poole and Partington (1980), Butross (1982), der Haroutunian (1983), Hoffman and Hoffman (1990), Choate (1993), Fuller (1994), Banerjee (1995), White (1996) and Saleh (1996).

Prior to 1950, the acceptability of yoghurt by communities in other parts of the world (i.e. Western Europe and North America) was limited to very small minorities and to some ethnic groups descended from the Balkans or the Middle East. The reason for this lack of popularity has been attributed to the fact that:

- natural yoghurt has a distinctive acidic, sharp flavour which can limit consumer acceptability;
- yoghurt does not play an important role in the diets of such communities;
- the type of food prepared does not require yoghurt as a raw material;
- the preference for other fermented dairy products, e.g. cheese;
- limited diversity of yoghurt and related products available on the markets;
- lack of consumer knowledge about the health properties of yoghurt and bio-yoghurts.

Despite the proximity of Europe to the Middle East, the popularity of yoghurt did not spread and it was not until the 1950s in Switzerland that a major development in the yoghurt industry took place, namely the introduction of fruit flavoured and sweetened yoghurt. Since that time the popularity of yoghurt had spread to other parts of the world, and consumption has increased significantly (see Table 1.2). It could be argued that the increased acceptability of yoghurt is the result of the fact that:

- Good marketing and advertising campaigns have been used to improve the image of the product and hence increase sales to the consumer.
- The production of low fat yoghurts has been used to encourage the diet conscious consumer to include it as part of his/her slimming programme.
- Communities in western Europe and North America have a preference for sweet products and hence the sweetened yoghurt was readily accepted.
- Yoghurt is consumed as an off-the-shelf dessert and not for the preparation of yoghurt dishes.
- Some of the yoghurt advertisements have been geared towards the younger generation and their response to the message has been enthusiastic.
- Continuous research and development is taking place in order to innovate yoghurt-based products which may lead to wider acceptability by the consumer.

Research and development is of great importance in the present context, for although many recent developments have their origin in the traditional processes, pressures from industry have elicited some interesting products. Some of these yoghurt-based products have been developed by industrial organisations and the available technical data are, as a consequence, somewhat limited. It was decided, therefore, to present the processing techniques in the form of schematic flow diagrams, for in this way the outlines of the process are more easily discerned; relevant scientific publications are referred to where possible. However, Mann (1987a, b, 1990a, b, 1992, 1995, 1996a–c) has published a "digest" of international dairy publications updating the technological and scientific aspects of yoghurt and related products and the reader is referred to some reviews for more information regarding indigenous fermented milk products in different countries (De, 1980; Beuchat, 1983; El-Gendy, 1983; Abou Donia, 1984; Jandal, 1988; FAO, 1990; Punjrath, 1991; Mathur, 1991; Gupta, 1992; Dirar, 1993; Kroger *et al.*, 1992; Kurmann *et al.*, 1992; Akin and Rice, 1994; Surono and Hosono, 1995; Steinkraus, 1996, 1997).

5.2 Standard commercial yoghurt

Commercial yoghurts are divided into three main categories, plain/natural, fruit and flavoured and these different types of yoghurt are manufactured in either the set or stirred/drinking form (see Fig. 1.3). The latter type is more popular and details of the different stages of the pre-paration of the milk base up until the addition of starter culture are given in Chapter 2. In brief the preliminary treatment of milk includes (a) the standardisation of fat content to 0.5–3.0 $g\,100\,g^{-1}$, (b) fortification of the milk solids-not-fat (SNF) to 12–14 $g\,100\,g^{-1}$, and (c) the addition of sugar and/or stabilisers (optional). The milk base is pre-warmed to about 60°C, homogenised at 17 MPa pressure, heated to 90–95°C for 3–5 min, cooled to 30–45°C and inoculated

with starter culture. Thus, the remaining manufacturing stages are illustrated in Fig. 5.1.

The current trend in commercial fruit yoghurt is towards a low calorie product. This can be achieved in many ways, for example by reducing the fat content in the milk base, by replacing the sugar with low calorie synthetic sweeteners, by replacing the milk fat with fat substitute (see Section 5.11), by the addition of dietary fibre preparations (Fernandez-Garcia and McGregor, 1997) and/or by reducing the milk solids-not-fat in the milk base and adding bulking agents like stabilisers. The latter aspect has been discussed in detail in Chapter 2 (see also Sato *et al.*, 1983; Bassett, 1983; Baker, 1983, 1985; Baker and Hulet, 1988, 1989; Marin and Zee, 1992; Ramaswamy and Basak, 1992; Nielsen *et al.*, 1993; Walther, 1995; McGlinchey, 1995; Cunin, 1997; Hunt and Maynes, 1997), whilst reference could be made to the following patent applications for a more complete discussion (Streiff *et al.*, 1990; Singer *et al.*, 1993; Shazer *et al.*, 1993; Mehnert, 1996).

In an attempt to improve yoghurt consumption in different markets of the world, the product has been mixed with a wide range of food ingredients in order to provide the consumer with flavours other than fruit types. Some examples may include the use of dried fruit and vegetable powders as additives which contain natural sources of pectin and vitamin C, and such yoghurts may have therapeutic effects for patients with digestive tract disorders (Arkhipova and Krasnikova, 1995). Alternatively, carrot pulp and natural extracts obtained from raw vegetables have been used to flavour the yoghurt (Ryckeboer and Louis, 1992; Vesely *et al.*, 1995), whilst Spillman and Farr (1983) evaluated consumer acceptability of a range of veg-

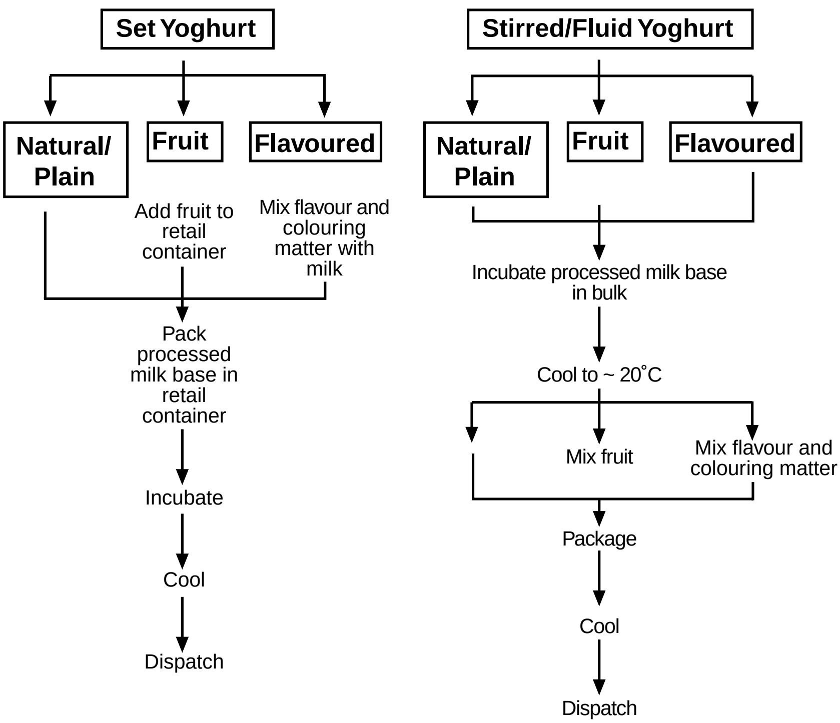

Fig. 5.1 Some of the manufacturing stages of flavoured yoghurts

etable flavoured yoghurts (cucumber, cauliflower, bean sprouts, groundnuts, celery, coconut and spices). Other proposed ideas are: (a) fruited yoghurts with added fibres from soya, oat and gum arabic (Hoyda *et al*., 1990) or cocoa pulp (Pina *et al*., 1998), (b) yoghurt for salad dressing containing salt, spices, dried onions, garlic and parsley (Steinberg, 1983a) or yoghurt dip with added onion, clam, Cheddar and blue cheeses (Steinberg, 1983b), (c) the use of puffed cereal grains that are specially treated (i.e. water-in-oil emulsion) so that the crisp texture of the cereal is maintained when mixed with yoghurt (Kaufman *et al*., 1990), (d) yoghurt fortified with calcium, which is a suitable vehicle to increase the calcium content of the product (Pirkul *et al*., 1997), and (e) special sweet toppings called "Sprinkl'ins" for a yoghurt dessert especially developed for children (Thøgersen, 1996). However, the swelling of cartons of yoghurt flavoured with cereals was attributed to the presence of *Mucor hiemalis* which appeared after 20 or 40 day storage at 12 or 5°C, respectively (Foschino and Ottogalli, 1989).

5.3 Yoghurt made from different mammalian milks

Sheep's, goat's and buffalo's milks are used for the manufacture of yoghurt and these milks are very popular in countries around the Mediterranean, Middle Eastern countries, southern Russia and the Indian subcontinent. Camel's milk may have been utilised by the nomads in the desert, but little published data are available. Although these milks are processed in a similar manner to cow's milk, the casein fractions differ, basically due to numerous breeds of goat and sheep compared with only a few among cows. According to reviews by Kalantzopoulos (1993), Bottazzi (1996) and Tamime and Marshall (1997), the reported quantities of casein components in these milks are:

- minor caseins: cow > sheep > buffalo > goat
- κ-casein: buffalo > goat > cow > sheep
- β-casein: goat > sheep > cow > buffalo
- α_s-casein: sheep > buffalo > cow > goat.

The extent of whey protein denaturation during heating is also different (Law, 1995) and, as a consequence, can affect the rheological properties of yoghurt. Specific studies on goat's, sheep's and buffalo's yoghurt has been reported by many researchers and, for this reason, the technological aspects of such products merit a separate review.

The fermentation of goat's, sheep's and buffalo's milks, including some aspects of the husbandry of these mammals, has been reported by IDF (1981, 1983, 1986, 1996), Epstein (1985), Kehagias (1987), Hansen (1989a), Boylan (1989), Anifantakis (1990), Abrahamsen and Rysstad (1991), Lokeshwar (1992), Mathur (1994), Kalantzopoulos (1994) and Gigli *et al*. (1996). However, some comparative studies using cow's, goat's or sheep's milk for the production of yoghurt give rise to the following suggestions: (a) For the production of drinking or natural set yoghurt, each type of milk should be concentrated to 18–35 g total solids (TS) $100\,g^{-1}$, diluted with equal volume of boiling water, spontaneously cooled to the incubation temperature and the milk fermented; this method of processing the milk produces good quality yoghurt but, with low fat milk, homogenisation is recommended (Renard, 1983),

(b) After growth of a mixed culture of *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* in milk, the expressed whey inhibited the growth of a wide range of undesirable and pathogenic micro-organisms; the inhibitory activity was buffalo > cow > goat (Singh and Kaul, 1982; Singh, 1983), (c) In Iraq, sheep's yoghurt was highly rated by a taste panel and was the firmest, whilst goat's and goat's + cow (50:50) yoghurts had the lowest scores; the starter (*Lactococcus lactis* subsp. *lactis* and *L. delbrueckii* subsp. *bulgaricus*) was recommended for making yoghurt similar to commercial products available in the market (Al-Dahhan *et al.*, 1984) and (d) Kehagias *et al.* (1988) evaluated the quality of cow's, goat's and sheep's yoghurt using different commercially available starter cultures.

5.3.1 Goat's milk yoghurt

The gross chemical composition of goat's milk can vary considerably and the total solids (TS) may range between 11.3 and 15.9 g 100 g^{-1} (Robinson and Vlahopoulou, 1988); the main causes of this variation are breed, stage of lactation, geographical location and diet. Such a view was confirmed by Kehagias *et al.* (1989) who reported that the best quality set-type goat's yoghurt was made from milk of indigenous breeds because it contained the highest TS. Whilst in India, Singh *et al.* (1991, 1996) reported that the growth of starter cultures in pasteurised goat's milk was faster than in boiled milk, that significant variation ($P < 0.01$) was observed in the growth of three mesophilic and four thermophilic starter cultures in milks obtained from four breeds of goat and that the lowest sensory scores were awarded to yoghurts made with *Lactobacillus acidophilus* and *L. delbrueckii* subsp. *bulgaricus*, and the highest to products made with single strains of *Lactococcus* species. The use of mixed strain starters improved the firmness of dahi (an Indian fermented milk) made from cow's, buffalo's or goat's milk (Katara and Lavania, 1991). However, the rate of acid development of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* in sterilised milk was in the following order: goat > goat + cow > cow (Bozanic and Tratnik, 1997; Bozanic *et al.*, 1998).

Thus, milk high in TS (*c.* protein 3.8 g 100 g^{-1}) should be used for yoghurt making and, as with cow's milk, different methods of fortification and processing of the milk can be used (Table 5.1, see also Park, 1994). However, the selection of starter cultures can greatly influence the organoleptic characteristics of goat's yoghurt (Castagnetti and Turtura, 1994). Whilst Ibrahim *et al.* (1990) observed enhanced growth, acid development and peptidase activity of *L. delbrueckii* subsp. *bulgaricus* in goat's milk, the observed inhibition of the yoghurt starter cultures in goat's milk could be associated with either milk containing strong "goaty" flavours or a higher concentration of free fatty acids than in cow's milk (Abrahamsen and Rysstad, 1991). Litopoulou-Tzanetaki *et al.* (1993) achieved a higher than usual concentration of acetaldehyde, diacetyl and acetoin in fermented goat's milk by using a mixture of a commercial yoghurt starter culture plus *Lactococcus lactis* biovar *diacetylactis*. In general, the citrate content in goat's milk is rather low when compared with cow's milk and, as a consequence, such milk may not be suitable for diacetyl production by mesophilic lactococci alone (Abrahamsen and Rysstad, 1991). However, low levels of acetaldehyde in goat's yoghurts have been attributed to the relatively high concentration of glycine in the milk; glycine can inhibit the enzyme involved in the conversion of threonine to acetaldehyde and glycine (Abrahamsen and Rysstad, 1991). The addition of threonine to goat's milk stimulated

Table 5.1 Some suggested processes employed during the manufacture of goat's milk yoghurt

Processes	References
Fortify the milk with 4% cow's skimmed milk powder (SMP), standardise the fat content to $2\,g\,100\,g^{-1}$, homogenise at 19.6 MPa and heat to 80°C for 15 min.	Duitschaever (1978)
Ultrafiltration (UF) and homogenisation of the milk improved the flavour and viscosity of the product.	Abrahamsen and Holmen (1981)
Procedures for making yoghurt and cheese from goat's milk on small farms have been detailed.	Flanagan and Holsinger (1985)
Addition of cow's SMP to goats milk helped to mask the goaty flavour.	Manjunath and Abraham (1986)
Improved coagula characteristics by addition of goat's milk powder or UF of the milk; reverse osmosis (RO) process did not provide a useful method of fortification.	Marshall and El-Bagoury (1986)
Flavouring of goat's yoghurt with guava or plum syrup ($18–20\,g\,100\,g^{-1}$) was not rated significantly different from cow's yoghurt.	Araujo *et al.* (1988)
Yoghurt made from goat's milk heated to 85°C for 20 min and incubated for 42°C for 3 hour was similar to a product made from a mixture of buffalo's and cow's milk.	El-Samragy (1988)
Homogenisation of the goat's milk and possibly the use of EPS starter cultures were identified as the most significant factors in improving the quality of stirred yoghurt.	Alexiou *et al.* (1990)
A selection of production methods have been illustrated in a patent.	Gabriel (1990)
UF of the milk to $16–18\,g\,TS\,100\,g^{-1}$ followed by heating to 90–92°C for 20 min helped to produce a typical Bulgarian yoghurt.	Baltadzhieva *et al.* (1991)
Fortification of goat's milk with 10% SMP improved the quality of zabadi (an Egyptian fermented milk).	Ahmed (1992)
Vacuum evaporation of milk, homogenisation and heating at 85°C for 15 min produced a thick yoghurt with improved flavour; the addition of stabilisers improved the physical and appearance properties of the product.	Abou-Dawood *et al.* (1993)

acetaldehyde production (Marshall and El-Bagoury, 1986; Rystaad *et al.*, 1990) and some relevant information regarding the behaviour and proteolytic activities of the yoghurt starter cultures in goat's milk have been reported by Telles (1988) and Abd-Rabo *et al.* (1992).

Inoculation rates (≤1.5%) of the yoghurt starter culture have been recommended by Vlahopoulou *et al.* (1994) to produce firmer gels, but other researchers have used ≥2% (Marshall and El-Bagoury, 1986; El-Samragy, 1988; Araujo *et al.*, 1988; Alexiou *et al.*, 1990; Baltadzhieva *et al.*, 1991). However, the viscoelastic properties of goat's yoghurt when using exopolysaccharide (EPS) cultures were lower (storage modulus G' and loss modulus G'' module) than those made from non-ropy starter cultures (Vlahopoulou and Bell, 1993) and similar observations were also reported for cow's milk yoghurt (see Chapter 2).

Nevertheless, EPS starter cultures produce thicker yoghurt and the product can be diluted with water (ratio 1:0.3 or 1:0.4) and $7\,g$ sugar $100\,g^{-1}$ added for the production of drinking yoghurt (van Dender *et al.*, 1991), whilst Hashimoto

and Antunes (1997) recommended the heat treatment of goat's milk at 90°C for >5 min during the production of yoghurt using EPS cultures. Alternatively, UF goat's milk retentate has been used to improve the characteristics and composition of a cultured-type beverage (Miocinovic *et al.*, 1990), whilst in Poland consumer acceptability of goat's fermented milk products were in the following order: drinking yoghurt > cultured acidophilus milk > kefir (Pieczonka and Pasionek, 1995).

5.3.2 Sheep's milk yoghurt

The technology of both traditional and industrial sheep's yoghurt have been reported by Irvine (1989) and Anifantakis (1990). The main differences in the manufacturing stages are first, in the traditional process the milk is boiled, filled into containers at 95°C, allowed to cool to 45°C, inoculated with starter culture and fermented to the desired pH, and finally transferred to the cold store; such a method produces a set-type yoghurt with a crusty layer. Second, the industrial process may include standardisation of the fat content, homogenisation and heating the milk to 95°C only. The addition of aroma (e.g. fruit or flavouring substances) is optional because the majority of sheep's yoghurt is sold unflavoured. The use of two-stage homogenisation at 13.8 MPa and 3.5 MPa, respectively, has been reported by Smith (1989), whilst Muir and Tamime (1993) have examined the effect of homogenisation of the milk on the extent of serum separation and firmness of set- and stirred-type sheep's yoghurt (see Fig. 5.2). Furthermore, using milk from a commercial flock of milking sheep in Scotland, details of the effect of seasonal variation on the gross chemical composition, changes in indices of stability, microbiological quality and organoleptic properties of yoghurt have been given by Muir *et al.* (1993a–c) and Tamime *et al.* (1993) (see also Bonczar *et al.*, 1998).

Inherently, sheep's milk contains high levels of protein (*c.* 5.8 g 100 g^{-1}), and does not require fortification of the milk SNF during the production of yoghurt (Muir *et al.*, 1993a). As mentioned elsewhere, homogenisation of the milk can improve the firmness (see Fig. 5.2) and reduce syneresis of sheep's yoghurt (Muir and Tamime, 1993), whilst Kisza *et al.* (1993) recommended heat treatment of the milk at 91°C for 30 s to reduce the fermentation time compared with cow's milk. The same

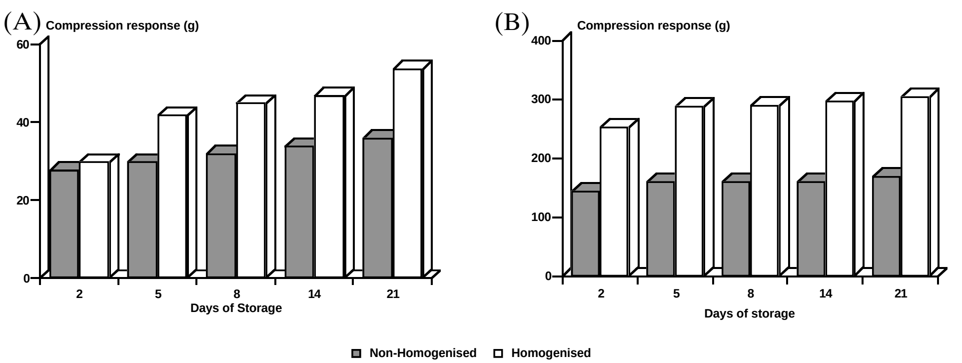

Fig. 5.2 Firmness of sheep's yoghurt (non-homogenised and homogenised) during storage for 21 days at 5°C

Data compiled from Muir and Tamime (1993).

Note: (A) Stirred yoghurt and (B) set yoghurt; to convert g force to Newtons (N), multiply 9.81×10^{-3}.

authors used a mixed starter culture consisting of *S. thermophilus* and *L. acidophilus* which resulted in a superior product when compared with a yoghurt starter culture (see also Creed, 1996).

Since the lactation period of sheep is about 6 months, the availability of milk for processing in dairies all the year around is limited. Hence a problem is encountered in maintaining a steady output and availability of sheep's yoghurt on the market. Some attempts have been made to preserve sheep's milk by freezing (Young, 1986, 1987; Giangiacomo and Messina, 1991). The stability of the milk during storage is governed by the temperature of freezing and the size of the block being frozen. Anifantakis *et al.* (1980) recommended the addition of 2 g 100 g^{-1} Na-citrate and 0.1 g 100 g^{-1} ascorbic acid before freezing in order to improve the stability during storage (i.e. up to 11 months) and after thawing when it is heated for yoghurt making. Oxidation of the fat was more pronounced in a 7 cm thick block of frozen milk stored at –20°C, in the presence of ascorbic acid, and when compared with a 2 cm block stored at –30°C; although the free fatty acid content increased during storage, the yoghurt made from the thawed milk was acceptable by the taste panel. However, in a recent study, Voutsinas *et al.* (1996a, b) concentrated sheep's milk by RO (whole and skimmed – the latter was mixed with the cream after concentration) before freezing, and they reported: (a) no significant differences in lipolysis during storage at –20°C for up to 8 months, (b) although the initial total viable and coliforms counts were high, the number decreased during storage, and (c) the thawed and reconstituted concentrates were stable for the production of yoghurt especially for whole milk, but the product had a slight grainy texture and the extent of syneresis was higher when compared with yoghurt made from fresh sheep's milk. These results may suggest, in part, some degree of storage stability of frozen sheep's milk, but more research is required to overcome some of the faults observed during the manufacture of yoghurt.

Isolates of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* from traditional Greek yoghurt have been characterised for flavour and proteolytic activity (Kalantzopoulos *et al.*, 1990a, b; Georgala *et al.*, 1995), and combinations of these organisms have been recommended for the industrial production of sheep's milk yoghurt. In an earlier study Kehagias and Dalles (1984) noted that the β-galactosidase activity of starter cultures in sheep's milk was double that observed in a similar product made from cow's milk. However, the screening and selection of lactic acid bacteria from gioddu (a Sardinian fermented milk made with an "artisanal" starter culture plus enzymic extracts of aromatising yeasts) resulted in a sheep's product with good keeping quality, improved flavour and appearance, and a firmer product with low syneresis (Deiana *et al.*, 1992).

5.3.3 Buffalo's milk yoghurt

In Egypt, small producers manufacture zabadi by boiling buffalo's milk for 30 min, cooling it to 40–42°C, inoculating with a starter (i.e. previous day zabadi) and incubating in the retail container. By contrast, the industrial process is similar to yoghurt making since the fat content is standardised to about 3 g 100 g^{-1}, the milk is then heated (e.g. 85–90°C for 5–10 min) and finally the milk is fermented in the retail container; the addition of flavour(s) is optional (Shalaby *et al.*, 1992; Mahran, 1996; Iniguez *et al.*, 1997; see also Garg, 1988). It is of interest to point out that homogenisation is not used during the preparation of buffalo's milk yoghurt, perhaps because the milk contains (g 100 g^{-1}) protein 4.3 and fat 8.6 (Spanghero and Susmel, 1996),

which is suitable for the production of a set-type yoghurt with a creamy layer. Furthermore, a similar processing approach (i.e. non-homogenisation of the milk) is found in countries where buffalo's milk is used for the production of other fermented milk products; Singh (1979) homogenised buffalo's milk, but the pressure(s) was not reported.

As with cow's milk, different fortification and/or fat standardisation methods have been used for buffalo's milk yoghurt. Table 5.2 illustrates some examples and the processing parameters. The use of buffalo's milk powder for fortification of the

Table 5.2 Some examples of processing buffalo's milk during yoghurt making

Comments	References
As with cow's milk, strain selection and combination is important to produce good quality buffalo yoghurt.	Lal *et al.* (1978); Khana and Singh (1979)
Use of a 5% inoculation rate and incubation at 43°C for 3 hours was recommended for skimmed buffalo yoghurt.	Patel *et al.* (1983)
Reduction of dissolved O_2 to $2.9\,\mu g\,g^{-1}$ in milk prior to heating at 90°C for 10 min increased the rate of acid development of the starter culture and the thiol content.	Shekar and Bhat (1983)
Lactose hydrolysis of the milk (30–40%) increased the acetaldehyde content in the product and gave the highest sensory score.	Abdou *et al.* (1984)
Milk preserved with lactoperoxidase required $1\frac{1}{2}$ hours more to reach the desired acidity in buffalo yoghurt.	Kumar and Mathur (1986)
Milk is concentrated to 1/2 or 2/3 its volume to produce yoghurt, but wheying was evident when the product was stored at 33–38°C.	Reddy *et al.* (1987)
Best misti dahi was produced from partially concentrated milk (about $18\,g\,TS\,100\,g^{-1}$) + sucrose $14\,g\,100\,g^{-1}$, using mixed strains of mesophilic starter cultures.	Gosh and Rajorhia (1990b)
Use of stored UHT milk ($g\,100\,g^{-1}$) (fat 4.5 and SNF 8.5) gave bitter sensory scores when compared with dahi made by heating the milk to 90°C for 5 min.	Sharma and Prasad (1990)
Addition of stabilisers to milk or reducing the fat content to $1.5\,g\,100\,g^{-1}$ decreased the diacetyl and volatile fatty acids levels in the product.	Shukla *et al.* (1986); Shukla and Jain (1991)
Addition of 10–12 g sucrose $100\,g^{-1}$ to skimmed milk inhibited the growth of *L. delbrueckii* subsp. *bulgaricus* during dahi production.	Amin *et al.* (1992)
Heat treatment of skimmed milk at 85°C for 5 min was recommended for yoghurt making in Spain.	Iniguez *et al.* (1992)
Standardisation of fat to $3\,g\,100\,g^{-1}$ and SNF to $10\,g\,100\,g^{-1}$ produced the best quality dahi.	Chawla and Balachandran (1993, 1994)
Milk heated at 80–82°C for 20 min, cooled to about 31°C, inoculated with single strain *S. thermophilus* and incubated for 10–12 hours produced an acceptable product	Tawfik *et al.* (1993)
Milk (fat $6.3\,g\,100\,g^{-1}$ and protein $4.7\,g\,100\,g^{-1}$) heated to 75°C for 5 min produced the most acceptable and firmest yoghurt.	Cardoso Castaneda *et al.* (1994)
Good bio-yogur was produced from mixed buffalo's (70%) and cow's (30%) milks that had been heated to 90°C for 5 min and fermented with *S. thermophilus* and *L. acidophilus*.	Iniguez *et al.* (1995)

milk is not widespread because it is not readily available, but recent studies of such a powder made from skimmed UF retentate have been reported by Patel and Mistry (1997). The gross composition ($g\,100\,g^{-1}$) of skimmed buffalo's milk powder is protein 67.5, fat 1.6, ash 8.6 and lactose 18.7.

Miscellaneous additives such as whey proteins (Ahmed and Ismail, 1978a, b), groundnut protein (Venkateshaiah *et al.*, 1982), defatted soyabean flour (El-Deeb and Hassan, 1987; Magdoub *et al.*, 1992), cooked wheat grain (Hamzawi and Kamaly, 1992) and cow's SMP (El-Shibiny *et al.*, 1977) have been used to fortify milk to produce an acceptable buffalo yoghurt. The use of membrane filtration is somewhat limited for the industrial production of buffalo yoghurt, but studies in this area have suggested: (a) a two-fold concentration by UF and standardisation of the fat content to $5.5\,g\,100\,g^{-1}$ was recommended by Haggag and Fayed (1988), (b) UF could be used to manipulate buffalo's milk, for example $10\,g\,SNF\,100\,g^{-1}$ or $11\,g\,SNF\,100\,g^{-1}$ plus $3\,g\,fat\,100\,g^{-1}$ for the production of zabadi (Khorshid *et al.*, 1992), and (c) RO of buffalo's milk >1.5-fold produced dahi that was very thick, lumpy, lacking flavour and had low acidity (Kumar and Pal, 1994).

Milk obtained from buffalos given a yeast culture in their feed affected the growth and biochemical behaviour of two mesophilic and three thermophilic single strains of lactic acid bacteria (Ibrahim, 1991). As the starter cultures employed for the production of dahi are not well defined, the general consensus is that yoghurt microfloras have been used, even though the preference in India may be to use mixed mesophilic strains including *Lac. lactis* biovar *diacetylactis* (Gosh and Rajorhia, 1990a). However, the antibacterial activity of *S. thermophilus* MD-2, MD-8 and D-3 strains in buffalo's milk dahi (i.e. $4.5\,g\,fat\,100\,g^{-1}$ and $10.5\,g\,SNF\,100\,g^{-1}$) against pathogenic micro-organisms was greater in the cell free extracts which may suggest that inhibitor substance(s) other than lactic acid may be present (Gupta and Tiwari, 1990; Dave *et al.*, 1992; see also Dzurec *et al.*, 1992). β-galactosidase activity of the same starter culture strains in dahi made up to $21\,g\,100\,g^{-1}$ TS was reported by Dave *et al.* (1993), whilst the incorporation of nisin into dahi and its effect on the yoghurt starter culture was studied by Gupta and Prasad (1988, 1989).

The microstructure of buffalo dahi is influenced by the level of heating applied to the milk. According to Tomar and Prasad (1989) milk heated to 70°C resulted in a product which was soft, had an open structure and the casein was near spherical in shape (i.e. a size of about 300 nm), whilst milk heated at 90°C for 30 min gave a firm curd and the micelle size was about 235 nm and elongated in shape; the protein matrix consisted of a long micellar chain (see also Turambekar and Kulkarni, 1991).

Thermisation of misti dahi at 65°C for 30 min decreased the starter cultures count (i.e. consisting of *Lac. lactis* biovar *diacetylactis* and subsp. *cremoris*) by about $3\log_{10}$ colony forming units (cfu) ml^{-1} and a further $1\log_{10}\,cfu\,ml^{-1}$ after storage at 30°C for 30 days (Chander *et al.*, 1989, 1992). A similar observation was reported by Sarkar *et al.* (1992a, b) when the product was heated at 60°C for 10 min (see also Mann and Joshi, 1997).

It was suggested that the nutritive quality of zabadi could be improved by the addition of electrolytic iron or ferric chloride up to $8\,mg\,100\,g^{-1}$ with no effect on the quality of the product (Mahran *et al.*, 1996). However, buffalo's milk fortified with groundnut or soya milk enhanced the growth of *Bifidobacterium bifidum*, whilst the addition of 3 mM glycine produced the firmest curd with a starter count $>1 \times 10^8\,cfu\,ml^{-1}$ at pH 3.89 (Murad *et al.*, 1997).

5.3.4 Camel's milk yoghurt

Camel's milk is popular in countries that have arid regions and tropical temperatures. It is generally opaque-white in colour. The gross chemical composition can vary considerably and the main causes of variation are breed, stage of lactation, type of fodder and availability of drinking water. Some data are available on the composition of camel's milk, and the range of the various components ($g\,100\,g^{-1}$) reported in a recent review are as follows: TS 9.8–14.4, fat 3.2–5.5, lactose 3.4–5.5, protein 2.7–4.5 and ash 0.6–0.9 (Hassan *et al.*, 1987; Hagrass *et al.*, 1987; Farah, 1993; see also Mohamed, 1990; Hafez and Hamzawi, 1991; Gorban and Izzeldin, 1997).

Farah *et al.* (1990) heated camel's milk to 85°C for 30 min, cooled it to 27°C and fermented it with mesophilic lactic cultures (homo- or hetero-fermentative) for 24 hour. The products were evaluated organoleptically by 13 Somali nomads, nine Somalis (i.e. city dwellers) and three Canadians, and at the same time compared with susa (a traditionally fermented milk from Somalia). The products were highly acceptable and similar to susa, and the authors recommended the controlled fermentation of camel's milk in rural areas in order to improve the quality of susa and utilise wasted surplus milk during the rainy season.

However, Gran *et al.* (1990) and Abu-Tarboush (1996) observed that the growth of mixed or single strains of *S. thermophilus* (four) and *L. delbrueckii* subsp. *bulgaricus* (three) was higher in cow's than in camel's milk, but proteolysis was higher in camel's milk. Nevertheless, in mixed cultures, the yoghurt starters released the same amount of free amino groups except for the *L. delbrueckii* subsp. *bulgaricus* strain LB12 (Abu-Tarboush, 1996). A similar behaviour was also reported for *L. acidophilus* and four species of bifidobacteria grown in camel's milk (Abu-Tarboush, 1994; Abu-Tarboush *et al.*, 1998).

5.4 Pasteurised/UHT/long life/heat shock yoghurt

Depending on the standard of hygiene observed during the manufacture of yoghurt and the microbiological quality of the ingredients and packaging materials, the shelf life of yoghurt is around 3–4 weeks under refrigerated conditions. Various techniques have been used in order to improve the keeping quality of yoghurt, such as:

- freezing and drying
- gas flushing
- addition of preservatives
- use of aseptic equipment

(discussed under separate headings elsewhere)

- application of multiple frequency microwaves
- sterilisation by heat

and each of these approaches has its adherents.

A post-production heat treatment helps to prolong the shelf life of the product, since the application of heat inactivates the starter culture bacteria and their enzymes, as well as other contaminants, for example yeasts and moulds. Traditionally, yoghurt was heated for a few hours over low fires of a special type of wood. The end product was referred to as smoked yoghurt (see Fig. 1.2) and it was preserved over the winter months by placing in jars and covering with either olive oil or tallow. However, in a mechanised plant, the time–temperature relationships

which are used to achieve the desired effect of pasteurisation are similar to those used for liquid milk processing, although in general a lower energy input is required for yoghurt since the level of acidity is much higher than in milk (Gavin, 1966; Puhan, 1979; Driessen, 1984).

5.4.1 Technology of manufacture

Two main problems have been associated with the manufacture of pasteurised yoghurt. First, a reduction in viscosity and whey syneresis may occur and second there may be loss of flavour (this is only significant in plain/natural yoghurt). Table 5.3 illustrates the heat treatments that can be applied to produce yoghurt with longer keeping quality. To overcome some of these problems, especially when yoghurt is heated to temperatures above 70°C, the following precautionary measures are recommended:

- Cooling the yoghurt first to 20°C, and then proceeding with the heat treatment; in some instances, the heating is in two stages (i.e. 60–68°C for 5–20 min followed

Table 5.3 Reported processing conditions for the manufacture of stirred-type pasteurised/UHT yoghurt

Time	Temperatures (°C)	Improvement of shelf life	References
30 min	50–55	3 weeks at 15°C	Rakshy (1966)
15–40 s	57–70	Reducing unwanted microbial counts	Sebela (1979)
20–30 min	58–60	Inactivation of β-galactosidase	Scolari *et al.* (1983)
5 min	58	Inactivation of yeasts	Waes (1987)
	60–65	40 or 10 days at 6–8°C and 15–20°C, respectively	Karabasevic *et al.* (1983)
	60–65	6–8 weeks at 12°C	Neirinckx (1972)
30 min	60	30 days at 20°C	Goh (1985)
1 min	60 or 70		Prekoppova and Slottava (1979)
5–20 min	60–68 then to 77	Aseptic yoghurt	Barua and Hampton (1986)
5 min	64	3 weeks at 20°C	Vanderpoorten and Martens (1976)
30 s	65		van der Loo (1980, 1981)
Flash	65–70	Hot filling	von Klupsch (1977a); Mulcahy (1972)
20 min	65	7 days at 27°C	Luck and Mostert (1971)
5 min	70	21 days at ~5°C	Mohammed *et al.* (1985)
30–40 s	70	Hot filling	Dellaglio (1977, 1979)
15–30 min	70	30 or 60 days at 20°C and 4°C, respectively	Guldas and Atamer (1996)
Few s	75	4–6 weeks at 20°C	von Schulz (1969); Bake (1979)
~2 min	85	No refrigeration required	Keefer and Murray (1988)
20 s	85	3 months at 37°C	McKenna (1987)
10–15 min	85–88	1 year at 20°C	Anon. (1979a)
27 s	85	>4 weeks at 20°C	von Holdt (1978)
	88	Few weeks	Hermann (1980)

by heating to 77°C) in order to stabilise the protein without gelatinising the added starch (Barua and Hampton, 1986).

- Homogenisation of the heated yoghurt before packaging is recommended, for example, cool the heated yoghurt to about 65°C, homogenise at 5 MPa, cool to 7°C add flavour and package (Hermann, 1980).
- Hot filling of yoghurt after pasteurisation is widely practised and final cooling takes place in the retail container (see Table 5.3 for illustrated examples).
- Addition of special stabilisers is sometimes recommended, but on average, <1 g 100 g^{-1} is added depending on the type used; the following are some examples: (a) carrageenan and starch plus citrate (Barua and Hampton, 1986), (b) xanthan and guar gum mixture at a ratio of 2 : 1 plus disodium phosphate (Hermann, 1980), (c) the use of Gelodan which is a mixture of starch, pectin, gelatin and milk proteins (Berg and Møller, 1994; Guldas and Atamer, 1996), and (d) agar, carrageenan or pectin plus citric acid (Keefer and Murray, 1988). However, Petersen (1989) reported that carrageenan is added as a texturiser and to rebuild the rheological properties of the product after heating.
- Recommended processing equipment should be used including plate, tubular or scraped surface heat exchangers and plant to package the heated yoghurt aseptically.

Set-type yoghurt can be heat treated in the retail container and some examples are 75°C for 5–10 min (Bake, 1979), 58°C for 5 min (van der Loo, 1980), 85°C for 35 min (Pavey and Mone, 1976), 65–85°C for 30–120 min (i.e. depending on the size of the pot in order to sterilise the centre of the product) (Deschamps, 1985), 60–85°C in an autoclave for up to 50 min and pressures up to 0.2 MPa (Egli and Egli, 1976a, b, 1977, 1980) and 72°C in a water bath for 30 min (Aziz, 1985).

It is evident, therefore, that it is technically feasible to prolong the shelf life of yoghurt by the application of heat, although some controversy may exist regarding its definition as yoghurt; most existing standards stipulate that yoghurt must contain an abundant and viable population of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* (Glaser, 1992). Tamime and Deeth (1980) suggested that it would be reasonable to reserve the term yoghurt for the traditional product and to designate the heat-treated product as pasteurised, UHT or long life yoghurt. Such an approach could help to ease the existing controversy, for essentially the only difference between pasteurised yoghurt and a traditional yoghurt is the low viable count of starter organisms in the former; this difference may, however, be relevant in relation to the nutritional and therapeutic aspects of the product (see Deeth and Tamime, 1981; Marshall and Tamime, 1997a, b; Buttriss, 1997, and Chapter 9). Nevertheless, von Klupsch (1977b) has recommended that the stability of heated cultured milk products should be tested during storage for 3 day at 30–37°C, 15 day at ambient temperature and 60 day at about 5°C, and the product should not show any sign of gas production or syneresis during these storage periods.

5.4.2 Processing effects on properties of product

The other constituents of yoghurt that may be most affected by heat are the vitamins and the enzymes. de Felip *et al.* (1979), comparing heated yoghurt (HY) and unheated yoghurt (UY), reported the following observations: (a) The thiamin content in both types of yoghurt was not affected by heat or cold storage, (b)

Vitamin B_6 losses appeared to be greater during the storage of HY than with UY, that is, 85% compared with 50%, (c) Folic acid decreased to a trace concentrations in HY after 15 days, but in UY a similar reduction took 30 days, (d) Pantothenic acid was initially reduced by 70% in HY, and (e) Heat treatment reduced the activities of the enzymes protease, cellulase, amylase and β-galactosidase by 60%, 25%, 50% and 100%, respectively. However, identification of the starter microflora in thermally treated, set-type, plain yoghurt using gene probes and polymerase chain reactions were dependent on the heat treatment applied and the results differed for the streptococci or lactobacilli (Lick *et al*., 1996).

The inactivation of β-galactosidase has been reported by many researchers (Speck, 1977; Speck and Geoffrion, 1980; Lusiani and Bianchi-Salvadori, 1978; Kolars *et al*., 1984; Gilliland and Kim, 1984; Savaiano *et al*., 1984; Savaiano and Levitt, 1987; McDonough *et al*., 1987; Schaafsma *et al*., 1988; Dewit *et al*., 1988; Lerebours *et al*., 1989; Pochart *et al*., 1989; Marteau *et al*., 1990) and the reviews by Rao *et al*. (1985), Bourlioux and Pochart (1988), Fernandes and Shahani (1989), Abrahamsen (1991) and Savaiano (1994) are recommended for further reading. The presence of this enzyme in yoghurt is highly desirable, particularly for consumers deficient in lactase. Gallagher *et al*. (1974) showed that yoghurt does not have the same adverse effects as milk on lactose intolerant patients and this benefit is due to the presence of active β-galactosidase; a test on lactose-intolerant humans fed heated yoghurt confirmed the effect by measuring hydrogen in the breath. However, Hottinger *et al*. (1992) patented a process for preparing a long-life yoghurt in which each microbial flora of the starter culture has a level of 10^6–10^{10} cfu ml^{-1} after heating; a mutant strain of *L. delbrueckii* subsp. *bulgaricus* is used which lacks a fragment of the DNA containing part of the β-galactosidase gene, to ensure the survival of the micro-organisms.

An alternative method, which can be used to pasteurise yoghurt, is the application of the multiple frequency or microwave technique, known as the Bach system. The principle of this method is well documented by Bach (1977, 1978) and, in brief, it consists of a two-stage, rapid dielectric heating of yoghurt in plastic cups. The first stage is applied horizontally (low frequency microwaves with high penetration), while the second stage is applied vertically (high frequency microwaves with low penetration). The actual pasteurisation is at a lower temperature than required for a conventional process and the treatment takes place during the passage of the yoghurt cups through a water bath. The two stages are complementary to each other and are needed to achieve adequate pasteurisation. According to Bach (1977), this system results in the destruction of yeasts and moulds, but has no adverse effect on the milk proteins or the starter bacteria; the keeping quality of yoghurt is extended to 4–6 weeks at room temperature. In addition, the use of this technique does not require the addition of special stabilisers to the yoghurt. According to Reuter (1978), the additional processing cost is marginal when set against the improved shelf life of the yoghurt.

5.5 Drinking yoghurt

5.5.1 Background

Drinking yoghurt is categorised as stirred yoghurt of low viscosity and this product is consumed as a refreshing drink. The traditional Turkish yoghurt drink is known

as ayran, and Akin and Rice (1994) have detailed the stages of manufacture. Ayran can be produced from full-fat milk, and after fermentation, the yoghurt is mixed with about 35% water and 1 g salt 100 g^{-1}, churned to remove the butter granules, packaged and stored at 5°C. However, if the fat is standardised to 1.5 g 100 g^{-1} and the SNF in the milk is not fortified, the stirred yoghurt (i.e. ayran) is mixed with salt (1 g 100 g^{-1}), packaged and stored in the refrigerator. The Turkish standard of ayran is as follows (g 100 g^{-1}): water 90.5, TS 9.5, SNF 8, lactic acid 1.6, salt 1 (optional) and free from pathogenic micro-organisms (Akin and Rice, 1994). In the Lebanon, a similar product to ayran is made from low fat milk and flavoured with mint extract.

The European and North American types of drinking yoghurt are made from a milk base low in fat and milk solids and the manufacture of such products is possible in most types of yoghurt plant. Under normal production practice the yoghurt coagulum is handled very carefully, but when drinking yoghurt is manufactured, the positive pumps are replaced with centrifugal pumps to transfer the yoghurt from the incubation tanks to the coolers. Alternatively, higher speeds of agitation are used to break the coagulum after fermentation, or sometimes the cold yoghurt is passed through a homogeniser without the application of pressure.

Up to the 1980s, relevant published data on drinking yoghurt were reported by many researchers (Pedersen and Poulsen, 1971; Grozdova, 1971; Rousseau, 1974; Morley, 1978, 1979a, b; Rhodes, 1978; Anon., 1979a, 1980a, 1981, 1986d; Lang, 1979, 1980; Ross, 1980; Hendricus and Evers, 1980; Yaygin, 1980; von Klupsch, 1981; Lavrenova *et al.*, 1981), whilst Mann (1983a, b, 1985a, b, 1988a, b) has published an update of the technological and scientific aspects of drinking yoghurt (see also von Klupsch, 1984; Charalambous, 1986; Driessen and Loones, 1992).

5.5.2 Processing aspects

According to Bylund (1995), commercial processes for the manufacture of drinking yoghurt could be classified into the following types:

- Homogenise stirred yoghurt, cool and package; shelf life 2–3 weeks at 5°C.
- Homogenise stirred yoghurt, pasteurise (i.e. low temperature) and aseptically package; shelf life 1–2 months at 5°C.
- Homogenise stirred yoghurt, UHT and aseptically package; shelf life several months at ambient temperature (see Fig. 5.3).

In general, milk alone is normally used for the production of drinking yoghurt but in some instances other food additives may be added to the milk. Some examples may include the addition of malt extract (Zobkova *et al.*, 1985), whey concentrate or soyabean flour (Rossi and Clementi, 1984; Kolesnikova *et al.*, 1986), whey: buttermilk mixture (60:40) (Srivastava *et al.*, 1985), processed tomato and SMP (Yokota *et al.*, 1989), sweet cream buttermilk (Choprea and Gandhi, 1989, 1990; Gritsenko *et al.*, 1993), enzyme-hydrolysed lupin seed milk (Han *et al.*, 1985), red ginseng extract (Song *et al.*, 1992) and yoghurt cultures and edible acid (Hidalgo and Dalan, 1984). It could be argued, however, that some of these products should be known as beverages rather than drinking yoghurts.

The milk base and any miscellaneous additives are normally fermented with a yoghurt starter culture, but a wide range of mixed cultures have been used. Some examples are shown in Table 5.4. Slow acidification of milk by *L. delbrueckii* subsp.

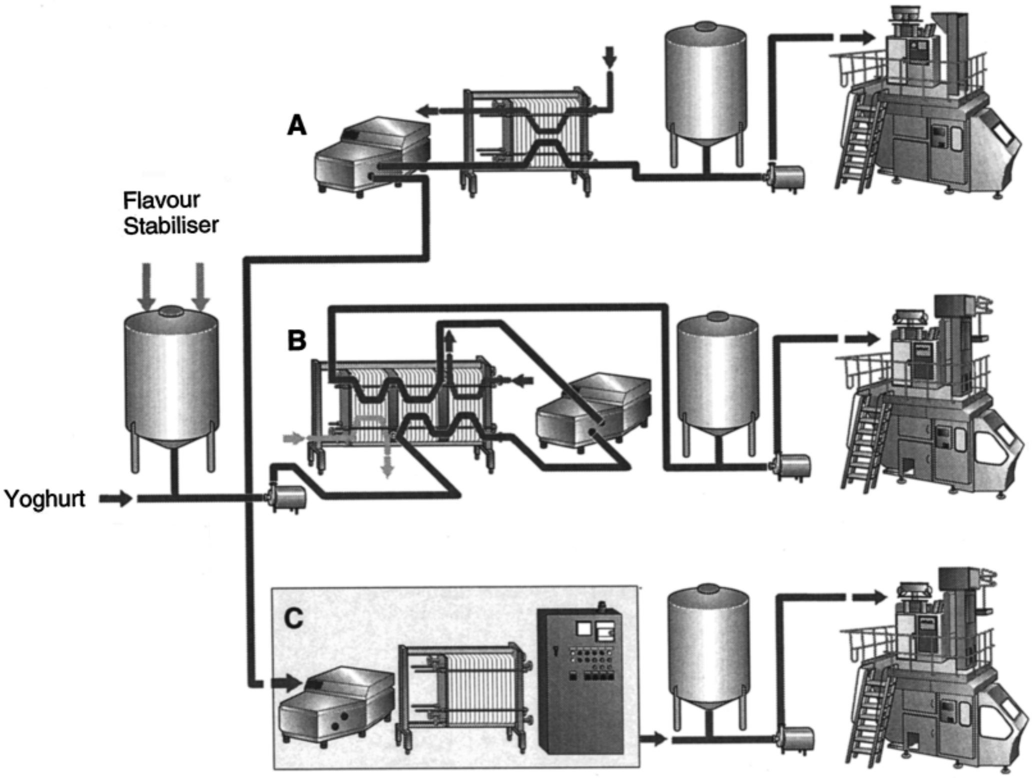

Fig. 5.3 Illustrations of some processing plants that could be used for the manufacture of drinking yoghurt with the anticipated shelf life indicated: A, homogenised and cooled, shelf life 2–3 weeks, refrigerated; B, homogenised, pasteurised and aseptically packaged, shelf life 1–2 months, refrigerated; C, homogenised, UHT treated and aseptically packaged; shelf life several months at room temperature

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Table 5.4 Some examples of starter cultures used for the manufacture of drinking yoghurt or beverages

Micro-organisms	References
S. thermophilus and *Lac. lactis* subsp. *lactis*	Koroleva *et al*. (1985)
L. delbrueckii subsp. *bulgaricus, L. paracasei* subsp. *paracasei*, *Lac. lactis* subsp. *cremoris*, *Lac. lactis* subsp. *lactis* and *Acetobacter aceti*	Kolesnikova *et al*. (1986)
Yoghurt culture, *L. acidophilus* and *B. bifidum*	Rossi and Clementi (1984)
L. delbrueckii subsp. *bulgaricus*	Siscar *et al*. (1985)
L. paracasei subsp. *paracasei*	So (1986)
S. thermophilus (single strain) or with *L. acidophilus*	Srivastava *et al*. (1985), Han *et al.* (1985) and Yukalo *et al*. (1991)
L. delbrueckii subsp. *bulgaricus* and/or *Lactobacillus helveticus* with or without *S. thermophilus*	Yokota *et al*. (1989)
L. delbrueckii subsp. *bulgaricus* and *L. acidophilus*	Choprea and Gandhi (1989, 1990)

bulgaricus and *Lactobacillus paracasei* subsp. *paracasei* for >48 and 140 hours, respectively, helped to minimise the precipitation of protein in the product (Kang and Lee, 1985; So, 1986). However, whey separation may be a problem during the manufacture of drinking yoghurt and it is necessary to incorporate a stabiliser into the milk base (Towler, 1984; Foley and Mulcahy, 1989; Tuohy, 1990). Syneresis was miminised in a cultured beverage made from sweet buttermilk by the addition of gelatin or carboxylmethyl cellulose (Choprea and Gandhi, 1990), apple pectin paste (Yukalo *et al.*, 1991) or about 0.4 g 100 g^{-1} Mexpectin RS450 (Anon., 1983a, 1984). van Hooydonk *et al.* (1984a, b) reported that variations in the sequences of processing of drinking yoghurt (e.g. homogenisation following instead of preceding pasteurisation or with homogenisation both before and after pasteurisation) did not affect the stability of the product; they recommended that single homogenisation at ≥15 MPa was sufficient in the presence of added pectin (about 0.4 g 100 g^{-1}). A similar view regarding the effect of upstream homogenisation (i.e. prepasteurisation) or with downstream homogenisation (i.e. after pasteurisation) on the stability of laban (a Middle Eastern natural yoghurt) was put forward by McKenna (1987). However, storage studies at different temperatures on the shelf life of liquid yoghurt were reported by Lee *et al.* (1993) and the product was stable for 16 days at 5°C and 10°C, 12 days at 15°C and 6 days at 20°C; the viable cell counts of the yoghurt organisms were selected as an index of quality that could be related to the sensory taste of the product during storage.

Drinking yoghurt is normally flavoured with fruit purees or juices and consumers studied in the U.S.A. preferred strawberry and raspberry (White *et al.*, 1984; Ryan *et al.*, 1984), while in Germany, sensory tests with children aged between 8–14 (n = 222) have identified the optimum sugar content as 8.3 g 100 g^{-1} (Endres, 1992). However, consumer attitudes to natural fruit juice versus added flavours and colorants in drinking yoghurt were in favour of the former product (Cramwinckel and Herstel, 1988a, b). Other fruit flavours which have been used in drinking yoghurt are carrot and apple concentrate (Kolesnikova *et al.*, 1986), pineapple (Srivastava *et al.*, 1985), lemon or orange concentrates (Arsov, 1983) and fruit juices, concentrates or essences (Evers, 1983).

The processing of drinking yoghurt at the Dan-Maelk factory in Denmark has been given in detail (Anon., 1986a–c). The gross chemical composition of the product (g 100 g^{-1}) is: fat 3.5, protein 3.8 and sugar 8; sterile fruit (i.e. free from stabilisers and preservatives) is added at a rate of 15 g 100 g^{-1}. The product is packaged aseptically in a screw cap gable carton using a Cherry-Burrell QL-9 machine fitted with a Posi-Fill® rotary-type valve that can handle fruit pieces up to 1.3 cm. Illustrations of other types of containers (cartons, glass bottles or non-translucent plastic bottles) that are used to package drinking yoghurt have been reported (Anon., 1987a, 1989, 1997; Kimbrell and Willman, 1993; Reiter, 1994). However, the ability of plastic bottles to absorb flavour compounds from drinking yoghurt has been studied by Linssen *et al.* (1992) (see also Chapter 2 and Section 2.13.5 and Tagliaferri, 1989).

The chemical composition of drinking yoghurt may vary from one country to another to meet consumer demand and a typical formulation (g 100 g^{-1}) might be as follows: fat up to 1.5, milk SNF about 9, sugar up to 8, stabiliser(s) about 0.5, fruit syrups or puree 5–15. As mentioned elsewhere, the product is sometimes heat treated (pasteurised or UHT) in order to prolong its keeping quality. Nevertheless, no appropriate data are available on the overall sales of drinking yoghurt in dif-

ferent markets but in the U.S.A. the sales of such products in 1992 were estimated to be about U.S.$ 13 million (Pontikis, 1992). Also as mentioned in Chapter 9, ayran was used successfully for oral administration of rehydration salts and was preferred by children to water for the treatment of gastroenteritis (Caglayan *et al.*, 1989).

5.5.3 Other beverage products

Soft drinks are extremely popular worldwide and, according to Duitschaever and Ketcheson (1974), a yoghurt beverage (flavoured with natural orange, lemon, cherry or apple) has the effect of improving the thirst quenching quality and refreshing taste of ordinary yoghurt and causing a pleasant tingling sensation on the tongue. However, the fermentation of milk by lactic acid bacteria and yeasts is widely used in east Europe and Russia for the manufacture of kefir and koumiss, and this type of fermentation releases lactic acid, alcohol, carbon dioxide and aromatic flavouring compounds into the product. A process has been developed for the Japanese market in which a yeast (genus *Kloeckera*) is precultured in the milk before the production of yoghurt. The milk is then sterilised, cooled to incubation temperature and finally inoculated with a mixed culture of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus*. Details of the process have been reported by Kuwabara (1970). The yoghurt beverage has the following characteristics: it contains aromatic flavouring compounds produced by the yeast, but no alcohol or gas: it contains a higher viable cell count of the starter cultures than conventional yoghurt, since the yeast metabolites enhance the activity of the starter culture; and the beverage does not suffer from whey separation.

A rather different Bulgarian beverage, which is specially formulated for the market in Russia, consists of 35–54% yoghurt, 20–40% natural fruit or vegetable puree, 28–30% syrup plus apple pectin and 0.1–0.2% citric acid. The mixture is homogenised, sterilised at 120–130°C for 50–70 s, cooled and packaged (Arolski *et al.*, 1979), but the popularity of the product, particularly against a wider market, has not been tested. Kondratenko (1994) reported a high protein product made from high protein powders (casein and blood hydrolysate or casein and whey protein) and cultured with *L. delbrueckii* subsp. *bulgaricus* ($\leq 2.5 \times 10^9$ cfu g^{-1}) which is suitable for dietetic or sports purposes; this product could be consumed as a beverage rehydrated in milk, water or juice. Alternatively, yoghurt-like beverages could be made with vegetable flours (soyabean, peas, lupin and horse bean) fermented with a yoghurt starter culture; however, reduced lactic acid production was observed when compared with a milk-based beverages and *L. delbrueckii* subsp. *bulgaricus* exhibited no significant growth (Rossi, 1982).

5.5.4 Carbonated yoghurt

Carbonated yoghurt can be manufactured in either a liquid or a dry form. The former type is, in effect, a carbonated, flavoured drinking yoghurt, while the dry mix gradually releases carbon dioxide (CO_2) when the powder is reconstituted with water. Liquid carbonated yoghurt can be made using one of the following techniques. (a) A soya protein whipping agent is used with stabilisers (carboxymethylcellulose and xanthan gum) in the yoghurt/milk mixture; the liquid product, on shaking, develops frothiness which is maintained during consumption (Igoe and

Taylor, 1983). (b) The processed milk base is carbonated with CO_2, followed by fermentation with the starter culture (Castberg and Rystaad, 1990; see also Meyer and Mizandjian, 1991). (c) Carbonation of a yoghurt beverage was achieved by homogenising the product (i.e. yoghurt containing sugar and type 428 yoghurt stabiliser) at 4.8 Pa and 4°C (Choi and Kosikowski, 1985; Driessen and Loones, 1992).

The dry carbonated yoghurt has been explained in detail by Schenk (1980). He has reported the following advantages when using certain carbonates: (a) The presence of metal carbonates in the mix tends to neutralise the acid in the yoghurt, so that carbonated yoghurt is less acidic and has a pH around 7, (b) Although different types of metal carbonates could be used, the addition of calcium carbonate rather than sodium carbonate is advantageous; the former compound tends to dissolve at a slower rate in water, and so gradually releases the CO_2 into the reconstituted product, otherwise the carbonated yoghurt tends to go flat within a very short period of time, and (c) The addition of various types of calcium compound to the dried mix improves the opacity of the carbonated yoghurt, since the calcium reacts with various acids to form insoluble salts (see also Anon., 1998). However, the beverage concentrate, details of which have been given by Kolesnikova *et al.* (1986), could be diluted with carbonated water to produce a fizzy beverage (see Section 5.5.2).

5.6 Lactose hydrolysed yoghurt (LHY)

During the manufacture of yoghurt, only part of the available lactose is utilised by the starter culture bacteria as an energy source with the production of lactic acid. The excess lactose could be utilised to sweeten the yoghurt without increasing its calorific value. This effect could be achieved by hydrolysing the lactose using β-galactosidase (in powder or liquid form), which splits the lactose into glucose and galactose; the relative sweetness of lactose and these monosaccharides is, compared to a degree of sweetness for sucrose equal to 1, as follows: lactose 0.4, galactose 0.6 and glucose 0.7. Commercial preparations of β-galactosidase are mainly produced from yeasts, fungi and, to a lesser degree, bacteria (Broome *et al.*, 1983, Gunther, 1984). However, Engel (1973) observed that only 50% hydrolysis of the lactose was necessary to produce an acceptable yoghurt in terms of sweetness. Up until the late 1970s, relevant data on the manufacture of LHY were reported by Tamime (1977a, b, 1978a) and reviewed by Driessen and Loones (1992), IDF (1993) and Khedkar *et al.* (1994). The process of lactose hydrolysis in milk could be carried out using one of the following methods:

- Process A – low temperature hydrolysis at <10°C during overnight storage;
- Process B – high temperature hydrolysis at 30–35°C for $\frac{1}{2}$ hour;
- Process C – high temperature hydrolysis at 30°C where the enzyme is added to the processed milk base along with the starter culture.

In processes A and B it is essential to agitate the milk and to adjust the pH to about 6.6; proceed to manufacture the yoghurt as illustrated in Fig. 5.1. Inactivation of the β-galactosidase is achieved by the heat treatment. In process C, the slow rate of acid development by the starter culture gradually reduces the β-galactosidase activity and total activation may occur below pH 5.0 (see also Lelieveld, 1984).

Hydrolysis is only desirable, of course, during the manufacture of fruit/flavoured yoghurt, since plain/natural yoghurts are not sweetened at all. Nevertheless, although a reduction in the level of lactose in natural yoghurt does improve its therapeutic value (Gallagher *et al.,* 1974), current clinical studies confirm that β-galactosidase originating from the starter culture is sufficient for lactose maldigestors, and there is no need to hydrolyse the lactose in the milk base (Rosado *et al*., 1992; Rosado, 1998; see also Chapter 9). However, work in this field has associated the enhanced activity of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* in lactose hydrolysed milk with the availability of glucose and/or galactose in the milk. Hemme *et al*. (1978, 1979) and Marschke and Dulley (1978) have detected some proteolytic activity in commercial samples of β-galactosidase (possibly due to contamination during its preparation) and the improved activity of the yoghurt starter culture may be associated with the liberation of essential amino acids (Lee *et al*., 1990a) rather than with the presence of glucose and/or galactose. Nevertheless, despite these contradictory views, many researchers have reported shorter coagulation times for the lactose hydrolysed milks (Ismail and El-Nimer, 1980; Dariani *et al*., 1982; Effat *et al*., 1983; Shchelokova *et al*., 1985; Kreuder, 1988; Arsov, 1990). However, Arsov and Godic (1993) and Arsov and Torkar (1995) concluded that the causes of increased activity of starter cultures in lactose hydrolysed milk could be determined more clearly only using a pure culture of *S. thermophilus*. In a separate study, Arsov (1990) observed no enhanced activity by one of two commercial yoghurt starter cultures, while Sharma and Dutta (1986) suggested that stimulation of acid production by either of the yoghurt organisms in hydrolysed milk was strain dependent.

The quality of LHY may be influenced by a multitude of factors. First, lactose-hydrolysed milk can have an inhibitory effect on the growth of some strains of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* in mixed culture (Abd El-Hady *et al*., 1985). Second, some β-galactosidase preparations may cause off-flavours in the product when hydrolysis levels exceed 60%, while others are suitable at 80% hydrolysis (Dariani *et al*., 1982; Broome *et al*., 1983; Toba *et al*., 1986a). Consequently, yoghurt treated with β-galactosidase during fermentation received slightly lower scores for flavour, texture and consistency than the control (Ismail *et al*., 1983).

On some occasions it may be desirable to use the β-galactosidase of *Aspergillus oryzae* to obtain a higher oligosaccharide content (4–19 times) then that obtained with the control yoghurt (Toba *et al*., 1986b). However, the use of hydrolysed whey concentrate or hydrolysed reconstituted SMP and dried whey may cause gelation of the milk base or affect curd stability of the yoghurt, and the recommended processing methods for LHY have been reported by Shah and Jelen (1987), Shah *et al*. (1993) and Atamer *et al*. (1995). Also, if the use of lactulose in the manufacture of LHY is desired, it should be added after the lactose hydrolysis in order to reduce the loss of lactulose due to β-galactosidase activity (Olano *et al*., 1986). Furthermore, an alcoholic LHY beverage can be made from either whey or skimmed milk using β-galactosidase from *A. oryzae* and fermentation with *Zymomonas mobilis* and *L. delbrueckii* subsp. *bulgaricus* for ethanol and lactic acid production, respectively (Miyamoto *et al*., 1987).

Further processing methods to produce low calorie and low lactose yoghurt may include: (a) combined UF and β-galactosidase hydrolysis of milk which produces yoghurt with a lactose level $<0.1\,g\,100\,g^{-1}$ (Streiff *et al*., 1990; Khorshid *et al.*, 1993; Abbas *et al*., 1996a–c; see also Shady and Abdel-Razik, 1997), (b) production of a

good quality yoghurt with *L. delbrueckii* subsp. *bulgaricus* alone in hydrolysed milk fortified with glucose oxidase and hydrogen peroxide (Tahajod and Rand, 1993), and (c) the use of a β-galactosidase preparation from lactic acid bacteria rather than yeasts (Sinha and Dutta, 1985; Kobayashi *et al.*, 1989; Toba *et al.*, 1990; Yang *et al.*, 1993; Somkuti and Steinberg, 1995).

It is clear, therefore, that yoghurt can be produced from lactose hydrolysed milk, but the incentive for commercial production is limited because the process is still not economic in comparison with the addition of normal sweetening agents. However, Smith and Bradley (1984) have reported a net saving of U.S.$0.0061 *per* 227 g cup of sundae-style LHY and a similar view was confirmed by Botha *et al.* (1987). Alternatively, the production cost of LHY could be reduced by replacing SMP with a whey/caseinate blend in the milk base before hydrolysis (Whalen *et al.*, 1988). It could be argued of course, that the use of immobilised enzymes might offer an attractive solution, but the economics of the process will be the decisive factor.

5.7 Concentrated/strained yoghurt

5.7.1 Introduction and nomenclature

Traditionally, the containers used by the nomads in the Middle East for the production of yoghurt were made from animal skin and the yoghurt was left in these skins until it was consumed. While the yoghurt was hanging in the animal skin some of the liquid phase would have been absorbed into the skin, while some of the whey that had seeped through the skin would have been lost by evaporation. In this way concentration of the product took place and the new product was referred to as concentrated/strained yoghurt. This latter product would have had a better keeping quality than normal yoghurt, mainly as a result of the higher concentration of lactic acid.

Evidence of the production of strained yoghurt can be found in many countries such as the Balkans, eastern Mediterranean, Turkestan and the Indian subcontinent. Table 5.5 shows the variety of names by which this product is known in different countries. For hygienic reasons, the use of cloth bags rather than animal skins is now widely practised. In some countries an attempt has been made to introduce standards, for example Lebanon (Anon., 1965), Jordan (Anon., 1980b; Ibrahim *et al.*, 1996) and Saudi Arabia (Salji *et al.*, 1983, 1987a, b), where it is stipulated that labneh (see Table 5.5) shall have a specific chemical composition based on fat, total solids and salt. The latter compound is basically added as a flavouring agent, as a preservative or, possibly, to neutralise the acidic taste of the product.

Labneh is normally consumed with bread as part of a main meal, but the possibility of promoting this product in Europe and North America has not seriously been considered. For example, a dairy spread in which labneh is mixed with chives or, alternatively, a dairy dessert made by mixing fruit/flavours with the concentrated product, could prove popular. A rather similar traditional Indian dish is called shrikhand, made from chakka and sugar. Nutmeg and saffron extract are used as flavouring agents (Ganguly, 1972). However, such products, including ymer (a Danish fermented milk product), are similar in composition to labneh (Table 5.6) and the only evident differences are that chakka is made from buffalo's milk (Atreja and

Table 5.5 Synonyms for concentrated/strained yoghurt in different countries

Traditional names	Countries
Labneh, labaneh, lebneh, labna	Eastern Mediterranean
Tan, than	Armenia
Laban zeer	Egypt, Sudan
Stragisto, sakoulas, tzatziki	Greece
Torba, suzme	Turkey
Syuzma	Russia
Mastou, mast	Iraq, Iran
Basa, zimne, kiselo, mleko-slano	Yugoslavia, Bulgaria
Ititu	Ethiopia
Greek-style	United Kingdom
Chakka, Shrikhand[a]	India
Ymer[a]	Denmark
Skyr[a]	Iceland

Data compiled from Azimov (1982), Tamime and Crawford (1984), Tamime and Robinson (1988), FAO (1990), Kassaye *et al.* (1991), Kurmann *et al.* (1992), Akin and Rice (1994) and Doeff (1994).

[a] Refer to text.

Deodhar, 1987) and both the Danish and Indian products are made with mixed strains of mesophilic lactic acid bacteria (see Section 5.3.3). The microflora of skyr, which is an Icelandic fermented and concentrated product, consists of a yoghurt starter culture, *L. helveticus* and lactose-fermenting yeasts (Tamime and Robinson, 1988).

5.7.2 Processing methods

The traditional method of production (i.e. home, rural and/or small scale) consists of straining cold and unsweetened natural/plain yoghurt using a cloth bag, animal skin or earthenware vessel (Yonez, 1965; Zmarlicki *et al.*, 1974a, b; Tamime and Robinson, 1978; Robinson, 1977). In some parts of the world, the large-scale manufacture of labneh is also possible using large cloth bags (about 25 kg capacity) which are piled on top of each other to assist in removal of whey. The cloth bag method, in comparison with large- or factory-scale operations, is slow, labour intensive, unhygienic, cumbersome and gives low yields due to residues left in the bag (Tamime, 1993; El-Samragy, 1997). The different methods available to manufacture strained yoghurt in large volumes are as follows:

- cloth bag or the "Berge" system
- mechanical separators
- ultrafiltration
- product formulation

5.7.2.1 Cloth bag or Berge system

The cold full-fat stirred yoghurt (natural/plain) is emptied into cloth bags, about 25 kg, and stacked on top of each other in a vertical press which is located in a refrigerated room. Pressure is applied in order to assist whey drainage for a duration

Table 5.6 Chemical composition ($g\,100\,g^{-1}$) of concentrated/strained yoghurt and related products

Country/produce	Total solids	Fat	Protein	Lactose[a]	Ash	References
Lebanon/labneh						
commercial (*n* = 3)	22.1	9.0	ND	ND	ND	Tamime and Robinson (1978)
standard	26.0	10.0	–	–	–	Anon. (1965)
Saudi Arabia/labneh						
commercial (*n* = 18)	22.9	7.6	9.6	3.8	1.2	Salji *et al*. (1983, 1987a, b) and Salji (1991)
standard	22.0	7.0	–	–	–	
Jordan/labneh						
standard	23.0	9.0	–	–	–	Ibrahim *et al*. (1996)
USA/labneh						
experimental (*n* = 3)	23.2	8.9	7.4	5.0	1.5	El-Samragy and Zall (1988)
UK/Greek style						
commercial (*n* = 4)	24.1	10.2	6.2	6.6	0.9	Tamime (1993)
experimental (*n* = 4)[b]	24.7	11.5	8.7	3.8	0.7	Tamime *et al*. (1989b, 1991b)
experimental (*n* = 12)[c]	23.0	10.8	8.0	3.5	0.7	
Egypt/labneh						
experimental	26.6	9.8	11.0	4.0	1.5	Hofi (1988)
experimental	26.1	10.0	10.3	3.6	1.1	
Greece/stragisto						
commercial	22.4	10.7	8.2	ND	1.7	Veinoglou *et al*. (1978)
India/chakka[d]	23.0	Tr	14.0	3.3	2.2	Tamime and Robinson (1988)
Iceland/skyr	20.9	0.4	15.8	3.6	1.0	
UK/labneh anbaris	31.2	4.8	18.6	7.0	ND	
Israel/labneh anbaris	46.5	20.0	17.7	4.0	3.4	
Ethiopia/ititu	20.9	9.1	7.2	ND	0.7	Kassaye *et al*. (1991)

[a] In some instances the lactose content was calculated by difference. [b] Product made by traditional (cloth bag) method. [c] Product made by UF of warm yoghurt. [d] Shrikhand is made from chakka sweetened with sugar and fortified with cream (Patel and Abd El-Salam, 1986; Boghra and Mathur, 1992).

ND, not determined; –, not specified; Tr, trace; *n*, number of samples tested.

of 12–18 hours. The pressing time can be reduced if the pressure is increased to $2\,kg\,kg^{-1}$ of yoghurt and labneh will be ready for packaging after pressing for 6 hours (Abou-Donia *et al.*, 1992b). Alternatively, a long and horizontal cloth filter can be used; the long sides are supported on poles and may be gently oscillated up and down, while slight lateral pressure is applied. This method of concentrating the yoghurt is known as the modified Berge system and was developed in France in the 1960s for the production of fresh curd cheese (Berge, 1964; Maggs, 1964; see also Töral *et al.*, 1987).

Preliminary studies on the effect of using various strains of yoghurt starter culture on the rate of whey drainage were first reported by Tamime (1977b, 1978b) and Tamime and Robinson (1978). They concluded that strains producing exopolysaccharides (EPS) are not suitable because of the longer time required for the removal of whey and that the best labneh was produced from $16\,g$ TS $100\,g^{-1}$ of yoghurt (see also Gilles and Lawrence, 1981; Jensen and Nielsen, 1982; Hamad and Al-Sheikh, 1989). Al-Kanhal (1993) observed that traditional labneh made from fresh milk had the best organoleptic scores when compared with a similar product made from recombined milk or cultured buttermilk concentrated using a quarg or nozzle separator. Fat losses in the whey were minimised during the manufacture of chakka or shrikhand by homogenisation of the milk base before the fermentation stage (Desai *et al.*, 1985; Patel and Chakraborty, 1988) or using less than 31 of fermented milk for concentration (Rao *et al.*, 1987). Alternatively, shrikhand could be produced from skimmed chakka, together with the addition of cream and sugar in order to reduce the fat losses (Rao *et al.*, 1987b) or fortified with iron (Boghra and Mathur, 1992; Boghra *et al.*, 1997).

Different methods that can be used for the manufacture of labneh-type products may include: (a) the use of a specially designed packaging container where the whey is drained from the yoghurt and collected at the bottom of the plastic cup (Varan, 1994; Grusin, 1994); an illustration of this system is shown in Fig. 5.4, (b) the use of high solids low fat yoghurt which can be mixed with cream and mashed fruit (Cavaliere *et al.*, 1994a), and (c) the use of vacuum filtration to concentrate the yoghurt (Akin *et al.*, 1995).

5.7.2.2 Mechanical separator

Dagher and Ali (1985) produced labneh from heated yoghurt by centrifugation for 5 min at different speeds between 4000 and 11 700 g, and organoleptically all these labnehs were similar to the control (cloth bag) samples (see also El-Kenany, 1995). Factory-scale production of labneh using the quarg or nozzle separator in Saudi Arabia has been reported by Salji *et al.* (1983, 1987a, b). Skimmed milk should be used for the manufacture of yoghurt and the fermented milk is stirred vigorously, thermised at about 60°C, filtered to remove any large clots, cooled to about 40°C and concentrated to $18\,g\,100\,g^{-1}$ solids, cooled to about 15°C, blended with cream or fruit (optional) and finally packaged. Further accounts of this process have been reported by Rasic (1987), Hansen (1989b), Lehmann *et al.* (1991), Mortensen (1995) and Bylund (1995) and a typical example is shown in Fig. 5.5. If whole milk is used instead, the nozzles of the separator will clog. Recent developments in the design of such separators have made it feasible to use fermented whole milk for the production of concentrated yoghurt (Lehmann *et al.*, 1991). After acidification, the fermented milk is processed as described above, but before the separation stage, it is de-aerated for 15–20 min to assist the separation of the whey in the separator. A

Fig. 5.4 Illustration of a specially designed packaging container in which the product is concentrated during storage, distribution and retailing

typical chemical composition ($g\,100\,g^{-1}$) for concentrated yoghurt is total solids 24 and fat 9.6, whilst the composition of the whey is $6.1\,g\,100\,g^{-1}$ total solids, consisting mainly of lactose and minerals, but about $0.5\,g$ fat $100\,g^{-1}$.

Recently, Kehagias *et al.* (1994) have reported that compositional differences between strained yoghurt and quarg can be attributed to the structural changes brought about during the fermentation of milk, that is, fast and slow acidification using thermophilic and mesophilic starter cultures, respectively. Also, the same authors (Kehagias *et al.*, 1992) reported differences in the yield and recovery of milk solids when using goat's or cow's milk (see Rao *et al.*, 1987b). In another process for the production of labneh, yoghurt is blended with 25–100% of its volume with brine (3–12 g salt $100\,g^{-1}$) and the mixture is concentrated using a centrifugal separator (Kharrazi, 1984).

Whey from milk coagulated in a smoked wooden vessel (gorfa) is removed gradually using a wooden pipette for the production of ititu in Ethopia (Kassaye *et al.*, 1991; Beyene and Abrahamsen, 1997). As the whey is removed, the gorfa is filled with fresh milk to provide an on-going fermentation and the concentrated product has a shelf life of two months without refrigeration. The precise role(s) of the smoking process are not known, but a similar effect was described by Kimonye and Robinson (1991) with respect to iria ri matii (a Kenyan fermented milk in smoked gourds). Similarly, the yoghurt can be heated gently and the whey allowed to drain to give concentrated yoghurt (Rasic, 1987); such a method of manufacture resembles the traditional process of ymer making.

5.7.2.3 Ultrafiltration (UF)

Two different systems of UF have been used for the production of labneh, the fermentation of UF retenate that has the solids content desired in the final product

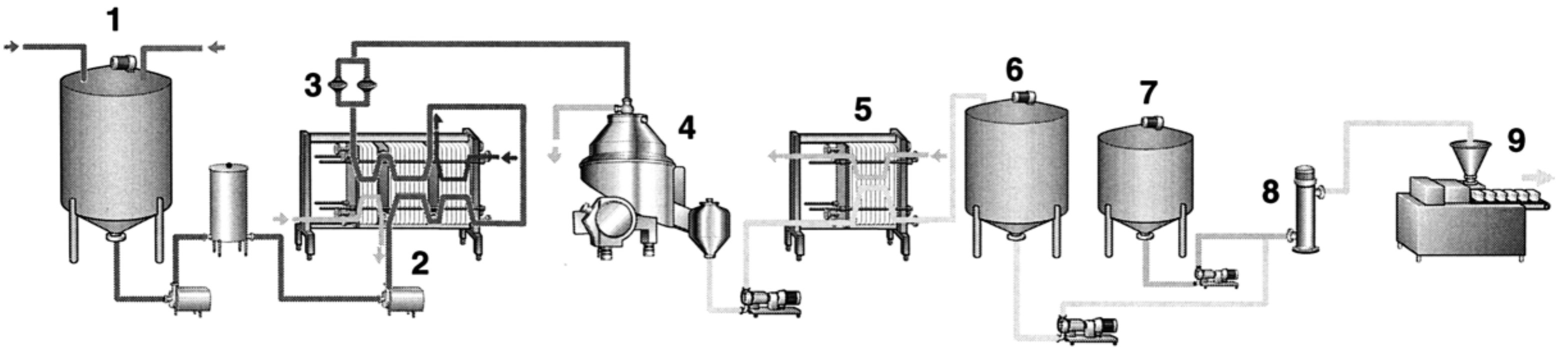

Fig. 5.5 Flow chart for the manufacture of strained yoghurt by mechanical separation
1, Ripening tank; 2, plate heat exchanger for thermisation; 3, filter system; 4, quarg separator; 5, plate cooler; 6, intermediate tank; 7, cream tank; 8, dynamic mixer; 9, packaging machine

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and UF of yoghurt at 40°C to produce a concentrate at about 24 g TS 100 g^{-1}. In the former system of production (Veinoglou *et al.*, 1978; Ibrahim, 1979; Abd El-Salam and El-Alamy, 1982; El-Samragy and Zall, 1988; Hofi, 1988, 1990; El-Samragy *et al.*, 1997) the UF retentate may be fermented in the retail container – as with the manufacture of natural set yoghurt – and the firmness of the product is much greater when compared with a similar product made using a traditional (cloth bag) method or by UF of warm yoghurt (Tamime *et al.*, 1989b). Also chakka and shrikhand have been produced by the UF technique where the yield has increased by 23% compared with the traditional method of manufacture and the UF product was highly rated (Patel and Chakraborty, 1985b, Sharma and Reuter, 1989, 1992).

According to Vesely *et al.* (1989), Robinson and Tamime (1993) and Tamime (1993), a wide range of UF plants are available on the market for the production of strained yoghurt on a large scale. A typical example is illustrated in Fig. 5.6 and according to the supplier, the manufacturing process is as follows. Standardised milk (e.g. 12.5 g 100 g^{-1} total solids and 3.5 g 100 g^{-1} fat) is preheated to 60°C, homogenised at 14.7 MPa, heated in a plate heat exchanger (PHE) to 95°C and held for 5 min in a holding tank before cooling to 40–45°C in the regeneration section of the PHE. After the fermentation period, the warm yoghurt is heated at 58–60°C for 3 min in the PHE, cooled to 40°C, concentrated in a two- to four-stage UF plant, cooled in a plate cooler to about 20°C and finally packaged. The degree of concentration using a four-stage UF plant, for example, could be adjusted to give 14, 16, 19 and 22 g 100 g^{-1} total solids, respectively. However, the highest flux rate during UF was observed at a temperature ≥50°C, but the total viable counts of the yoghurt starter organisms were lower than with labneh ultrafiltered at ≤45°C (Tamime *et al.*, 1991b). Attia *et al.* (1991a, b) reported that UF carried out at elevated temperatures >45°C increases the fouling rate of the UF membranes, which may affect the processing

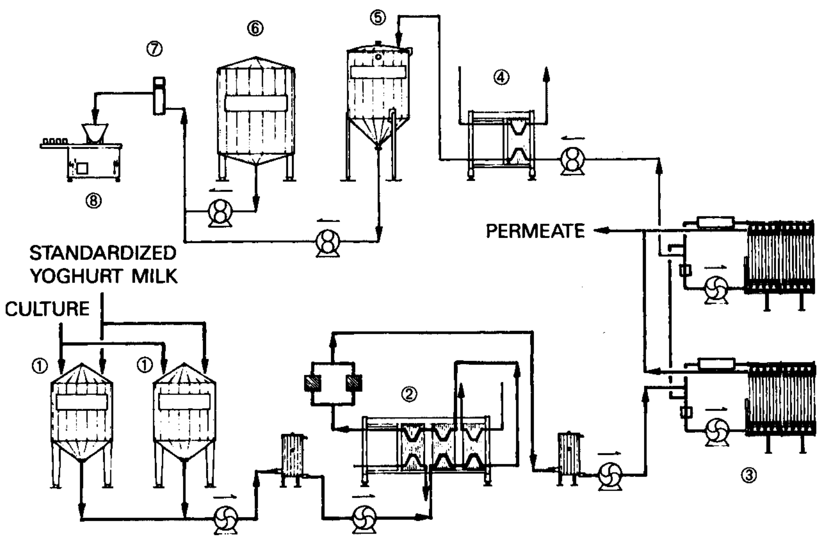

Fig. 5.6 Flow chart for the manufacture of strained yoghurt by UF
1, Fermentation tanks; 2, plate heat exchanger; 3, two- to four-stage UF plant; 4, plate cooler; 5, buffer tank; 6, fruit tank (optional); 7, in-line mixer; 8, packaging machine
Reproduced with courtesy of Tetra Pak (Processing Systems Division) A/B, Sweden.

conditions in large-scale operations where the equipment needs to be washed more frequently. It is possible to recommend that UF of yoghurt should be at 45–50°C, since at this high temperature, labneh can be produced within the shortest time and the firmness of the product is similar to traditional labneh (Tamime *et al.*, 1991b).

The ultrafiltration of heated (about 50°C) fermented and coagulated skimmed milk with different UF modules have been extensively studied by Sachdeva *et al.* (1992a, b) and Sharma *et al.* (1992a, b) for the production of good quality quarg. However, the concentration of L(+)- and D(−)-lactic acid in the product is governed by many factors such as the type of starter culture, the type of milk and the method of concentration, that is, UF or traditional method (Akin, 1997).

5.7.2.4 Product formulation

It is feasible to manufacture strained yoghurt from recombined dairy ingredients (Tamime, 1993). The process involves reconstitution of powder(s) in water and blending it with anhydrous milk fat, stabilizer (e.g. Cremodan Mousse 31, Danisco Ingredients (U.K.) Ltd.) and salt (optional). The recombined milk is handled and processed in a similar way to the production of yoghurt. After the fermentation stage, the product is precooled to about 20°C, packaged and the final cooling to 5°C takes place in the cold store. Typical compositions ($g\,100\,g^{-1}$) of strained yoghurts are full-fat: fat 10, SNF 14.8, salt 0.5, stabiliser 0.8 and total solids 26.1, and low-fat: fat 4.2, SNF 17.4, salt 0.5, stabiliser 0.9, total solids 23.0. However, as mentioned later, the rheological properties of recombined labneh will be different from those of labneh made by the traditional method or from UF retentate.

5.7.3 Miscellaneous properties

A wide range of aspects, besides the processing methods used for the manufacture of strained yoghurt, can affect the quality of the products.

The firmness of labneh (UF or traditional method) made from goat's or sheep's milk was lower than that of the cow's milk product (Mahdi, 1990; Mahdi *et al.*, 1990). However, the highest yield of strained yoghurt was for sheep > goat > cow (Giannoukou *et al.*, 1992), whilst in India, the yield of chakka was greatest with buffalo's milk (26.2%) and lowest with cow's milk (24.0%) (Subramonian *et al.*, 1995).

Standardisation of the milk base (cow's or buffalo's milk) is highly recommended to produce chakka with a specified compositional standard (Kulkarni *et al.*, 1995), a view which is applicable to labneh-type products as well. The utilisation of buttermilk or whey protein concentrates (WPC) has been successful for the production of labneh or chakka (El-Samragy *et al.*, 1988b; Mahfouz *et al.*, 1992; Al-Kanhal, 1993; Karthikeyan *et al.*, 1996). Gelatin (but not sodium alginate) can be used as an additive to improve the consistency of chakka (Desai *et al.*, 1987; Agnihotri and Pal, 1996, 1997), as does the use of Gelodan SB 253, Nisin and/or an EPS starter of *Leuconostoc* species (Sarkar *et al.*, 1996a, b).

Although the starter culture employed to ferment the milk during labneh making should consist of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus*, mesophilic lactic acid bacteria are widely used in India for the production of chakka. However, Patel and Chakraborty (1985a) recommended the use of a yoghurt starter culture instead as the fermentation time was reduced by 4–6 hours; addition of $10\,\mu g\,g^{-1}$ of diacetyl improved the flavour of the product (see also Khanna *et al.*, 1982; Patel

et al., 1993; Kadu *et al.*, 1994). A similar observation (i.e. reduced fermentation time) was also reported by Suryawanshi *et al.* (1993) and Subramonian *et al.* (1995, 1997) when using a combined starter culture of *S. thermophilus* and *L. acidophilus.* Rao *et al.* (1986, 1987b) reported that the highest yield and best organoleptic properties were observed in chakka made from milk fermented with *Lac. lactis* subsp. *cremoris*; labneh made with *B. bifidum* was not accepted by a taste panel due to the high level of acetic acid in the product (Mahdi, 1990; Mahdi *et al.*, 1990). The use of different starter culture combinations for making labneh were reported by Abou-Donia *et al.* (1992a) and Amer *et al.* (1997), whilst El-Samragy *et al.* (1988a) produced an acceptable labneh using *L. delbrueckii* subsp. *bulgaricus* in combination with *Enterococcus faecalis*.

The heat treatment of shrikhand at 70°C for 5 min extended the shelf life of the product to 15 days at 36°C or >70 days at <10°C, and it retained its overall acceptability (Prajapati *et al.*, 1991, 1992, 1993). Alternatively, Indian labneh packed in containers and covered with a layer of soyabean oil was still acceptable after 30 days storage at room temperature (Hassan *et al.*, 1986); a similar method is used in the Middle East to preserve labneh anbaris (see Section 5.7.5). Other modifications in the production methods of strained yoghurt may include lactose hydrolysis of the milk base (Tamime, 1978a, b; Tamime and Robinson, 1978), replacement of the butterfat with vegetable oils (Hefnawy *et al.*, 1992; Taha *et al.*, 1997a), addition of fruits (Bardale *et al.*, 1986), direct acidification of the milk (Ibrahim *et al.*, 1994) and carbonation of the milk for production of a gel rather than acidification or enzymatic coagulation (Caron *et al.*, 1992). The production of acetic and propionic acids is a method suggested by Haddadin *et al.* (1996, 1997) for utilisation of the whey from labneh (see also Atamer *et al.*, 1993).

The therapeutic and nutritional properties of strained yoghurt could be similar or slightly better than yoghurt. Thus, antibacterial properties of Indian fermented milk products against a wide range of pathogenic micro-organisms have been reported by Balasubramanyam and Varadaraj (1995) and Sarkar *et al.* (1996a), while a market survey in Egypt found that labneh ($n = 28$) contained different quantities of the vitamin B complex ($\mu g\,100\,g^{-1}$): niacin (93.2–184), biotin (1.3–2.6), vitamin B_6 (23.5–36.1), vitamin B_{12} (0.21–0.29) and folic acid (3.7–5.2). The addition of propionibacteria to the yoghurt starter culture increased the vitamin B_{12} and folic acid contents in labneh by 210% and 25%, respectively, whilst storage of labneh at 6°C for 10 day did not markedly affect their level (Khattab, 1991; see also El-Samragy *et al.*, 1997).

Ultimately, the microbiological properties of any type of strained fermented milk reflect the standards of hygiene during manufacture and the method of production. Thus, Lalas and Mantes (1984, 1987) reported that the low counts of lactic acid bacteria in strained yoghurt suggested that the yoghurt had been subjected to heat treatment before concentration, whilst the yeast and mould and total colony counts were $<25\,cfu\,g^{-1}$ and up to $6.8 \times 10^5\,cfu\,g^{-1}$, respectively. Yamani and Abu-Jaber (1994) found out that commercial Jordanian traditional labneh obtained from 18 dairy factories had mean psychrotropic and mesophilic counts of 2.6×10^6 and $4.4 \times 10^6\,cfu\,g^{-1}$, respectively, and these figures increased after 14 day storage at 7°C to 1.1×10^7 and $1.4 \times 10^7\,cfu\,g^{-1}$, respectively (see also Mihyar *et al.*, 1997). However, Upadhyay *et al.* (1984, 1985) found a positive correlation between the chemical changes and microbial counts of shrikhand and a sensory evaluation of fresh and stored samples.

In some instances, milk can be contaminated by undesirable components during the manufacture of strained yoghurt. For example, the radioactive material ^{131}I in milk (amounting to 6–12 kBq kg^{-1} which was equivalent to the dosages that Greece received during the Chernobyl accident) reduced the count of lactic acid bacteria in strained yoghurt by 45% (Vosniakos *et al.*, 1991). Hassanin (1994) reported that 70% of aflatoxin M_1 present in milk was recovered in labneh because this potential heptocarcinogen tends to be associated with the casein fraction of the product.

5.7.4 Microstructure

The microstructure of labneh (Fig. 5.7) made from cow's milk using the traditional (cloth bag) method, fermentation of UF retentate and UF of warm yoghurt, and the effect of smoothing these products by passage through a lactic curd structuriser was first reported by Tamime *et al.* (1989a). They found that: (a) SEM (scanning electron microscopy) at low magnification showed that there was no noticeable effect of the processing on the microstructure of labneh but, in some unsmoothed samples, small lumps of fluffy protein aggregates were found that were hollow and disappeared after smoothing (Fig. 5.7 a and b), (b) the microstructure of all the labneh samples at high SEM magnification were composed of casein particle chains and clusters and only subtle differences were observed; however, the smoothed samples

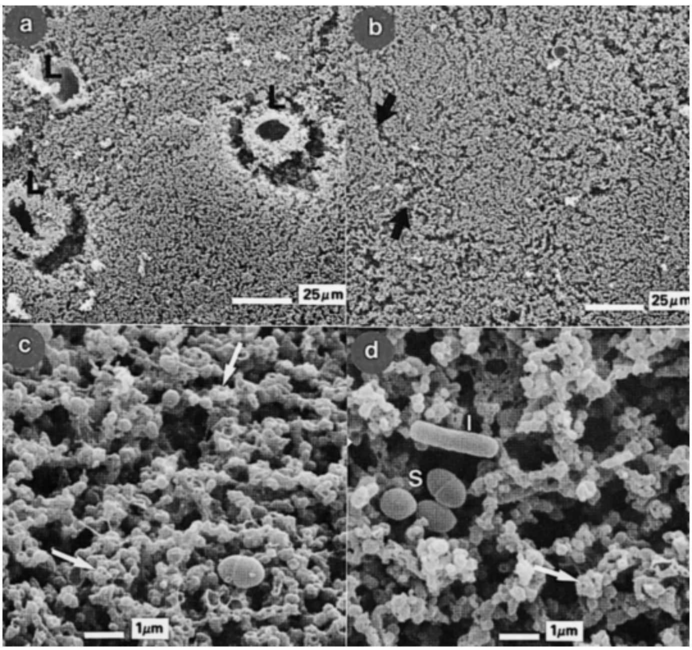

Fig. 5.7 Microstructure (SEM) at low magnification of UF labneh before (a) and after (b) passage through the lactic curd structuriser. L, small hollow protein lumps; black arrows in (b) show fluffy areas after the smoothing stage. Traditional (cloth bag) labneh at higher magnification before (c) and after (d) passage through the structuriser. Separation of fluffy areas (white arrows) is clearly noticeable; I, lactobacilli and S, streptococci

After Tamime *et al.* (1989a). Reproduced by courtesy of *Scanning Microscopy International.*

had slightly less compact and more open matrices, possibly due to the formation of larger pores as a result of the mechanical action of the structuriser (Fig. 5.7 c and d), and (c) a TEM (transmission electron microscope) examination of all the labnehs showed chains of agglomerated casein particles and fat globules; the chains were shorter after passage through the structuriser and there was some evidence of casein micelle fusion. However, in a separate study, Tamime *et al.* (1991a) found that the processing temperature (35–55°C) of UF resulted in an increase in the dimensions of the casein particles forming the protein matrix of the labneh (Fig. 5.8). Concentrating the yoghurt at 55°C resulted in the formation of complex micellar chains compared with the more simple structure of UF labneh concentrated at 35°C or the traditional product. Also the smoothed products appeared whiter and brighter, possibly due to the formation of appendages at the surface of the casein particles (Mottar *et al.*, 1987, 1989). Labneh made from goat's or sheep's milk was similar and less uniform than a similar product made from cow's milk (Tamime *et al.*, 1991c) (see Fig. 5.9).

As mentioned elsewhere, different methods for the manufacture of labneh are available. Ozer *et al.* (1997, 1998) have evaluated the rheological properties of prod-

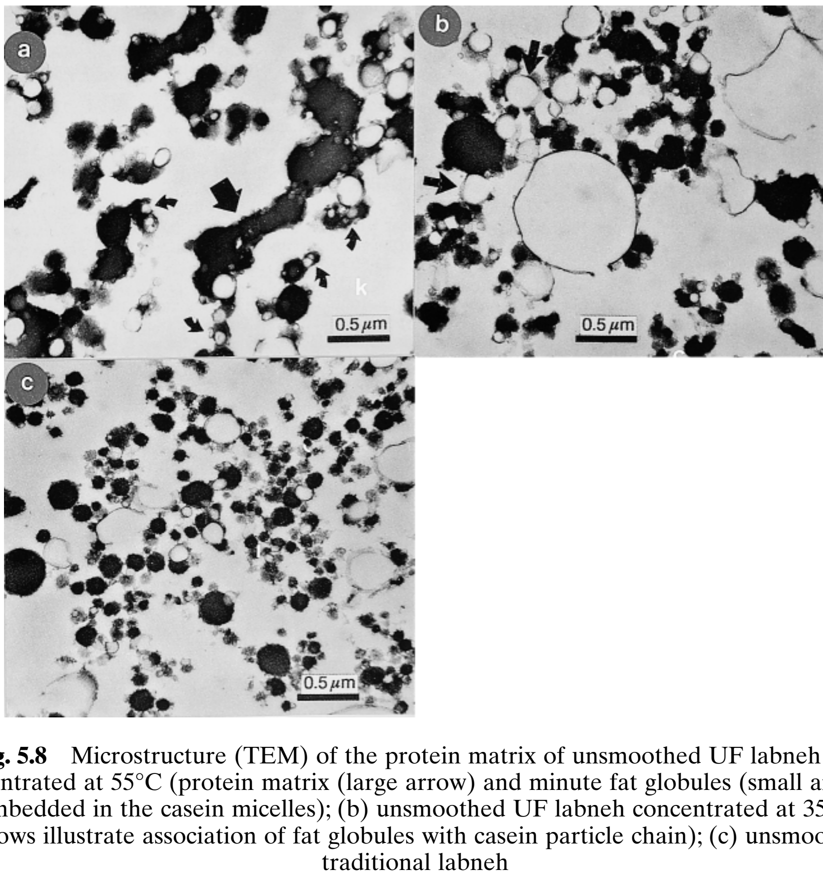

Fig. 5.8 Microstructure (TEM) of the protein matrix of unsmoothed UF labneh (a) concentrated at 55°C (protein matrix (large arrow) and minute fat globules (small arrows) embedded in the casein micelles); (b) unsmoothed UF labneh concentrated at 35°C (arrows illustrate association of fat globules with casein particle chain); (c) unsmoothed traditional labneh

After Tamime *et al.* (1991a). Reproduced by courtesy of *Scanning Microscopy International.*

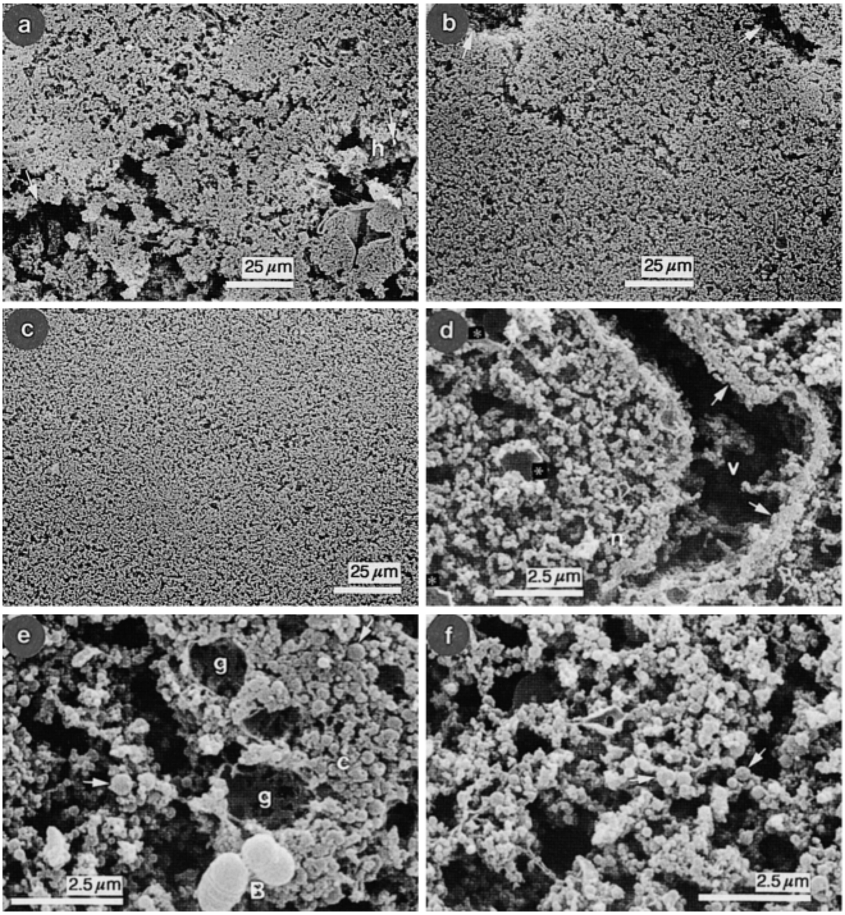

Fig. 5.9 Microstructure (SEM) of unsmoothed UF labneh made from goat's milk (a) contained many void spaces (arrows). Sheep's milk (b) was more uniform and cow's milk (c) had a uniform structure. (d) Sheep's labneh showing residues of fat globules membrane (asterisks); compact protein particles (arrows) formed the walls of a small void space (v) in the matrix. (e) Smoothed goat's labneh made by the traditional method and UF procedure (f); g, fat globule; B, bacteria; c, compact casein clusters and arrows illustrate large casein micelles which have smooth surfaces

After Tamime *et al.* (1991b). Reproduced by courtesy of *Scanning Microscopy International*.

ucts made by: (a) the traditional method of draining some of the whey from normal full fat yoghurt through a cloth bag, (b) concentrating full fat milk by UF or RO to 23 g 100 g^{-1} TS prior to fermentation, (c) concentrating full fat yoghurt (14–16 g 100 g^{-1} SNF) by UF or RO to 23 g 100 g^{-1} TS, (d) reconstituting full fat milk powder to give a milk base for fermentation of 23 g 100 g^{-1} TS, and (e) a combination treatment that might involve, for example, concentrating skimmed milk yoghurt by UF and adding cream to provide the desired fat content.

The precise choice of system will affect both the chemical composition and the physical properties of the end product and some typical figures are shown in Table

Table 5.7 Chemical composition ($g\,100\,g^{-1}$) of some samples of labneh made by different methods[a]

Product	Total solids	Protein	Lactose	Fat	Ash
Traditional method	23.3	8.0	5.2	9.2	0.8
UF (before fermentation)	22.4	8.3	5.2	8.2	0.8
UF (of yoghurt)	22.6	8.1	5.5	8.5	0.9
RO (before fermentation)	23.2	6.8	9.0	6.3	1.1
RO (of yoghurt)	22.2	6.4	8.8	6.6	1.0
Direct reconstitution	22.5	6.4	8.7	6.1	1.3

[a] For details refer to text.

After Ozer *et al.* (1997).

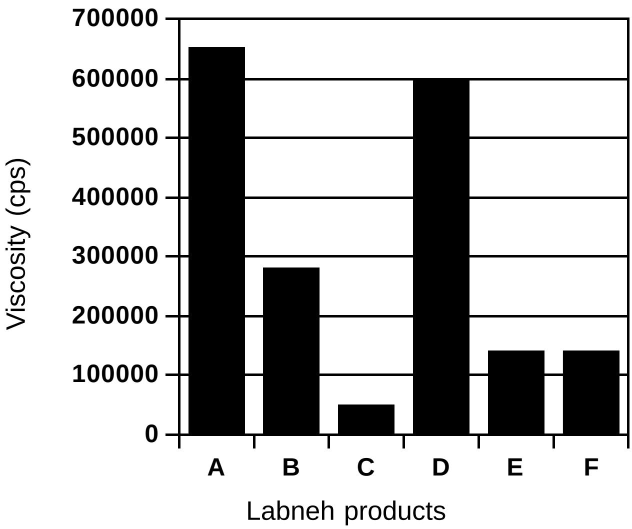

Fig. 5.10 Viscosity values of the test samples of labneh after overnight storage at 4°C. Results are average of three replicates

A, traditional; B, UF of yoghurt; C, RO of yoghurt; D, UF before fermentation; E, RO before fermentation; F, direct reconstitution

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5.7. The contrasting values for protein are of especial note with respect to the viscosity of the products and the effect of the higher protein levels is evident in Fig. 5.10. However, the precise level of protein is not the only factor to influence the physical properties, for it is clear that, while the traditional labneh has a lower protein content than the product made by UF of yoghurt, its viscosity is double that of labneh made from UF milk. It has been suggested by Ozer *et al.* (1997, 1998) that these variations are a reflection of structural differences between the gels, a point that is borne out to some extent by some dynamic rheological studies that were carried out using a stress-controlled rheometer. Thus, as shown in Fig. 5.11 and 5.12, the storage and loss moduli of labneh made by the various methods (see above) showed the same pattern as the results shown in Fig. 5.10. The differences are

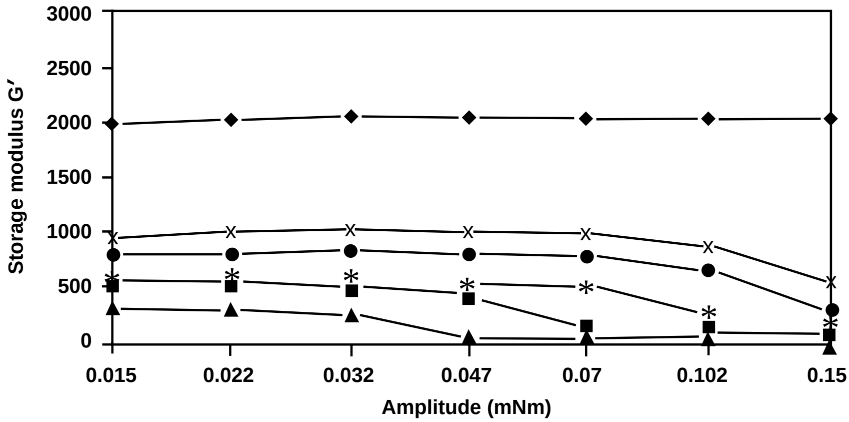

Fig. 5.11 Typical storage modulus patterns of different types of labneh after overnight storage at 4°C; test conditions are: amplitude range 0.015–0.15 m Nm, frequency 0.25 Hz, parallel plates (10 mm radius and 1 mm gap setting) at 25°C measuring temperature. Results are average of three replicates

–◆– Traditional; –●– UF of yoghurt: –▲– RO of yoghurt; –x– UF before fermentation; –*– RO before fermentation; –■– direct reconstitution

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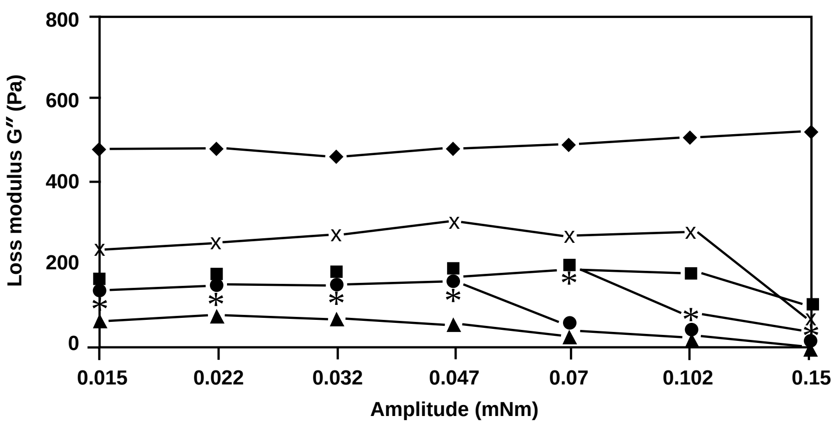

Fig. 5.12 Typical loss modulus patterns of different types of labneh after overnight storage at 4°C; test conditions are similar to those shown in Fig. 5.11. Results are average of three replicates

–◆– Traditional; –●– UF of yoghurt: –▲– RO of yoghurt; –x– UF before fermentation; –*– RO before fermentation; –■– direct reconstitution

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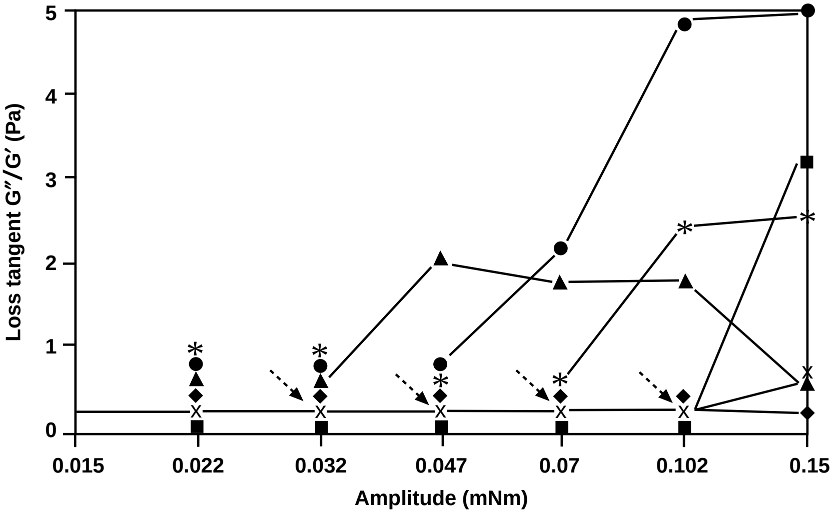

Fig. 5.13 Variation in loss tangent values of labneh samples as a function of amplitude; arrows indicate the breaking point of the structure in each sample. Results are average of three replicates

–◆– Traditional; –●– UF of yoghurt: –▲– RO of yoghurt; –x– UF before fermentation; –*– RO before fermentation; –■– direct reconstitution

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illustrated even more vividly by the calculations of the loss tangent values (Fig. 5.13) (G''/G') in that, while the structure of the traditional labneh did not break down at all under the experimental stresses applied, all the other samples showed some degree of instability. The labneh made from by UF (before fermentation) came structurally closest to the traditional product. This result confirms the proposal of Tamime *et al.* (1989a, b) that UF offers an excellent alternative to the cloth-bag method for making labneh. Nevertheless, the apparent superiority of the traditional labneh as revealed in Fig. 5.11 and 5.12 should be noted, for if the concentrated yoghurt is used as a base for a speciality like tzatziki, then the traditional product tends to give a better quality retail item.

5.7.5 Related products

Concentrated/strained yoghurt (i.e. labneh) is sometimes used as a raw material for the manufacture of some traditional dairy products popular in the Middle East. The process mainly involves extraction of more whey from the concentrated yoghurt and, in some extreme cases, the final product is dried (see Section 5.9). These traditional foods are produced from surplus milk during the spring and the summer months of the year and are used during the winter. Examples of such products are labneh anbaris and shankleesh or shankalish.

5.7.5.1 Labneh anbaris

This type of concentrated yoghurt has a total solids content between 30 and 40 g $100\,g^{-1}$ (Tamime and Crawford, 1984) and in some instances even higher (Rosenthal

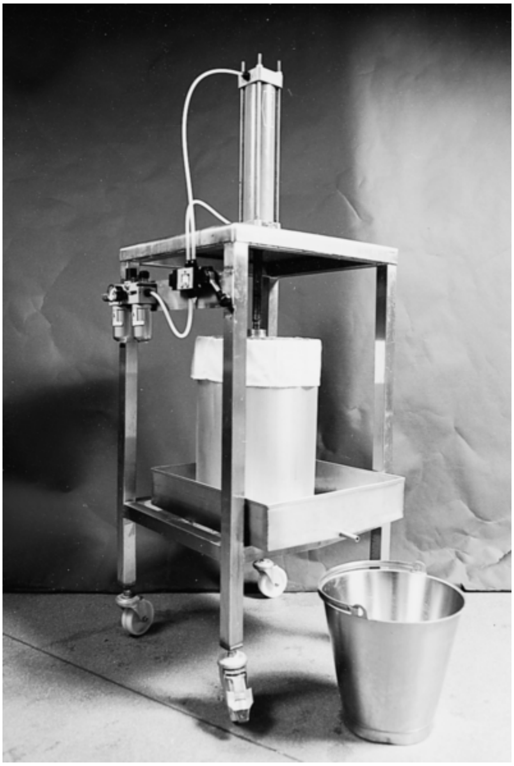

Fig. 5.14 Small-scale vertical press for the production of labneh anbaris or yoghurt cheese

et al., 1980) (see also Table 5.6). The traditional process starts with labneh (24 g TS 100 g^{-1}) and the end product is shaped into balls and partially sundried. Alternatively, the labneh is pressed for a longer duration to remove more whey (see Fig. 5.14; Hessabi, 1995) and then it is shaped into balls; however, by using this method to produce high solids strained yoghurt, aerial contamination with micro-organisms could be minimised. The balls are then placed in earthenware vessels or glass jars and further preserved in olive oil (see Fig. 5.15). In areas where goat's and/or sheep's milk is used to replace cow's milk, the end product is much stronger in flavour.

As long as the product is kept submerged in olive oil, the shelf life of the product is about 12–18 months at ambient temperature. Tamime and Crawford (1984) preserved labneh anbaris with K-sorbate (0.1 g 100 g^{-1}) or by heating the product in oil at 65°C for 55 min. After one year of storage at 20°C, the microbial counts in the control (without any treatment), K-sorbate or heated products were: (a) total viable count (non-lactic acid bacteria); 3.0×10^4, 4.5×10^3 and 2.0×10^2 cfu g^{-1}, respectively, (b) yeast and mould counts; $>1.0 \times 10^3$ cfu g^{-1} in the control sample and no growth at 10^{-1} dilution in the experimental products, and (c) coliforms were not recovered in any of the samples.

The consistency of this product resembles "lactic curd" or "pates fraiches" cheese, and Davis (1971) reported on a similar product called "yoghurt cheese". The typical

Fig. 5.15 Illustration of labneh anbaris preserved in olive oil

manufacturing process for "yoghurt cheese" is as follows: heat milk (whole or skimmed) to 70°C, cool to 46°C, add yoghurt starter culture and gently stir. Allow the milk to cool to 30°C without agitation, add the following ingredients (annatto, rennet and starter culture consisting of *Lac. lactis* subsp. *lactis* and subsp. *cremoris*), stir for 2–3 min, and after 2–3 hours cut the coagulum coarsely (2–3 cm in size). Run the curd and whey (by gravity) into a coarse cloth bag, drain the whey for 24 hours at 20–25°C and transfer the curd into a clean coth bag. Re-suspend for further draining for 24 hours at 5–10°C. Mix the curd with sorbate and salt (optional), pack and store under refrigeration.

A typical analysis ($g\,100\,g^{-1}$) of yoghurt cheese would be:

Product	Total solids	Protein	Fat	Lactose	pH
Experimental	40	15.0	17.2	5.5	3.8
Market in Qatar	Nd	20.0	22.0	7.6	3.95

Nd: not determined
After Keceli (personal communication).

Given that the water activity (A_w) of the test sample was 0.85, the salt content was $1.0\,g\,100\,g^{-1}$ and the pH was 3.8, it is not surprising that the product was microbiologically stable. In fact, the only real problem could be fungal growth on the surface of such products, a risk that, in practice, is eliminated by the anaerobic conditions imposed by the covering of olive oil.

In Poland, pre-concentrated milk (e.g. $30–40\,g\,100\,g^{-1}$ TS), is used to manufacture a product called super yoghurt, and this approach could help to overcome the hygienic problems associated with the use of the cloth bags. However, a novel cultured milk product called YoCheese has been developed in the U.S.A. and has the combined attributes of cottage cheese and yoghurt (Willrett *et al.*, 1990). Similarly in Japan, yoghurt made with *S. thermophilus, L. acidophilus* and *Bifidobacterium* sp.

was added to a soft-type cheese (i.e. similar to cream cheese or quarg in appearance) for the production of yoghurt cheese (Ariga *et al.*, 1989).

5.7.5.2 Shankleesh or shankalish

The procedure for the manufacture of shankleesh is somewhat similar to that of labneh anbaris differing only in the following aspects: (a) it is made from either low fat yoghurt or the fermented buttermilk which is the by-product of ghee making, (b) herbs and/or spices such as thyme (*Thymus vulgaris*) are added and (c) during the ripening or maturation period in earthenware jars, indigenous moulds grow on the surface of the product and participate in the biochemical changes that occur. Thus, according to Toufeili *et al.* (1995), this fermented milk product could be classified as a surface mould ripened cheese variety, the only indigenous type native to the Middle East.

Shankleesh, in the Lebanon, is normally made from sheep's milk, but local dairy factories also produce it from goat's and cow's milks. In some instances, the product is not mixed with herbs but is sold as white shankleesh. According to Dagher (1991), Robinson (1995a) and Toufeili *et al.* (1995), the manufacturing stages for shankleesh are as follows: dilute cold yoghurt with iced water, churn to remove the butter granules, heat the buttermilk at 90°C for 15–20 min to maximise the floculation of the proteins, cool and strain in a cloth bag for 48 hours at 6°C. Traditionally, the concentrate is mixed with salt, spices and herbs, shaped into large balls, partially dried in the sun and placed in earthenware jars to ripen at ambient temperature for one month; however, during this period moulds grow on the surface and before dispatch, the balls are washed with water, and covered with powdered thyme (Dagher, 1991). Alternatively, the shankleesh could be partially dried in an oven at 60°C until the moisture is about 64 g 100 g^{-1}, prior to the curd being mixed with salt (2.5 g 100 g^{-1}), kneaded manually and shaped into balls (i.e. 100 g each). The balls are then placed in earthenware jars and matured at 6°C and 85% relative humidity (Toufeili *et al.*, 1995).

The compositional quality of shankleesh may vary from one country to another due to inherent differences in the traditional methods used to manufacture this product. Table 5.8 illustrates the proximate gross composition of traditionally and laboratory-made shankleesh. This product and labneh anbaris are normally con-

Table 5.8 Proximate chemical composition (g 100 g^{-1}) of traditionally and laboratory-made shankleesh

Product type	Moisture	Protein	Fat	Lactose	Ash	References
Traditionally made						
NR	30.0	–	12.3[a]	–	–	FAO (1990)
NR	44.0	35.0	5.6	3.0	12.2	Dagher (1991)
Laboratory-made						
Cow	59.8	33.0	2.0	2.3	2.0	Toufeili *et al.* (1995)
Goat	58.9	31.4	4.0	2.6	3.1	Toufeili *et al.* (1995)
Sheep	56.0	32.2	6.1	2.8	3.0	Toufeili *et al.* (1995)

NR, not reported.

[a] The fat content was calculated from the reported fat-in-dry matter content.

sumed with bread and olive oil as appetisers, and the possibility of developing such products for markets in Europe and North America, perhaps as basic ingredients for the preparation of cocktail dips, clearly exists.

5.8 Frozen yoghurt

5.8.1 Background, standards and marketing

Frozen yoghurt is classified into three main categories, soft, hard or mousse (Fig. 5.16). These products resemble ice cream in their physical state and they are characterised simply as having the sharp, acidic taste of yoghurt combined with the coldness of ice cream. In addition these products contain high levels of sugar and stabilisers/emulsifiers compared with yoghurt, since these compounds are required during the freezing process to maintain the air-bubble structure.

The historical background of, and technical data on, frozen yoghurt has been discussed in detail by Kosikowski (1977), and Mann (1977, 1979) has compiled several international digests on frozen yoghurt; Lang (1979) and Rothwell (1993) have also reviewed developments in this field. In most countries, frozen yoghurt does not have national standards of identity in terms of chemical composition, minimum yoghurt content, heat treatment of the yoghurt/ice cream mix before freezing and the count of the starter microflora at the time of consumption (Mitten, 1989; Kimbrell *et al.*, 1990; Rothwell, 1993; Childs, 1994; Anon., 1995a, 1996; Westerbeek, 1995a, b, 1996). However, Westerbeek (1996) has pointed out that, in the Netherlands, the standards for frozen yoghurt stipulate that it should contain a minimum yoghurt content $\geq 70\%$ and have a pH <5, but in the U.S.A., consumers favour frozen yoghurt higher in pH (Brown *et al.*, 1991a). Little data are available on the production figures and market of frozen yoghurt in different countries but, in the U.S.A. (Knuston, 1978; Dryer, 1994; Keehner, 1996) in 1993, the market volume was about 550 million litres.

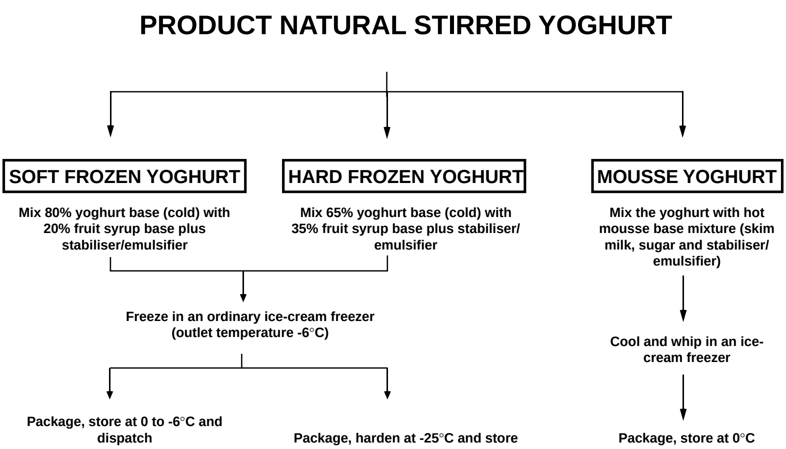

Fig. 5.16 Frozen yoghurt

For further information refer to Kurmann (1969), Crisp and John (1969), Ziemba (1971), Anon. (1977b, 1978a, 1979b), Igoe (1979a), Redfern and Rizk (1979), Gautneb *et al.* (1979), Hekmati and Bradley (1979), Kankari and Antilar (1980), Hulsbusch (1980), Kosikowski (1981), Bradley and Hekmati (1981), Miles and Leeder (1981) and Bray (1981).

5.8.2 Technology of manufacture

In general terms, the various stages involved in the manufacture of the different types of frozen yoghurt are similar (see Fig. 5.16) and some recipes for frozen yoghurt prior to the 1980s have been reported by Bradley and Winder (1977), Collins (1977), Chandan (1977), Mitten (1977), Grosser (1978), Morris (1979) and Speck and Hansen (1983). Basically, the process consists of mixing cold, natural stirred yoghurt with the cold fruit syrup base, stabilisers/emulsifiers and sugar (the latter ingredients are added hot for the manufacture of mousse yoghurt (see Fig. 5.16), then freezing the mix in a conventional ice cream freezer. The chemical composition of the yoghurt/fruit mix and the temperature during storage can ultimately affect the physical characteristics of these frozen yoghurt products, and Table 5.9 illustrates some suggested formulae for their manufacture; the recommended percentages of yoghurt and fruit range from 65–80 to 20–35%, respectively.

More recently, McGill (1995) has patented a container for tempering and dispensing frozen products including frozen yoghurt, while other processes for the manufacture of frozen yoghurt may include:

- no fermentation of the milk base
- direct or indirect fermentation of the milk base (Olsen, 1990a, b; Anon., 1993a).

Thus, these products may be made from yoghurt or a blend of ice cream mix containing sugar and yoghurt at a ratio of 50:50 to make frozen yoghurt with 89–90% overrun (Olsen, 1990a). Also, in some instances the processed milk base or ice cream mix could be inoculated with concentrated starter culture before freezing (Olsen, 1990b). Figure 5.17 shows a flow chart of the equipment required for the production of frozen yoghurt (see also Bylund, 1995), and the following patents provide some additional information (Carvel, 1990; Curry and Beach, 1991; Bee *et al.*, 1994; Heinrich, 1995).

Although the procedures for manufacture are well established, the following recommendations may help to eliminate defects in frozen yoghurt. (a) Ensure that the fruit syrup base is pasteurised and, except in the case of mousse yoghurt, cold prior to its addition to the yoghurt. (b) Gently mix the yoghurt and fruit syrup base, since vigorous agitation can lead to loss of the refreshing taste in the frozen yoghurt. (c) Replace the air at the whipping/freezing stage by nitrogen to achieve a longer shelf life for frozen yoghurt (Jochumsen, 1978). (d) Replace the normal sweetening agent

Table 5.9 Suggested chemical composition ($g\,100\,g^{-1}$) of frozen yoghurt mixes

Ingredients	Frozen yoghurt		
	Soft	Hard	Mousse
Fat	2–6	2–6	3
Milk SNF	5–10	5–14	12
Sugar	8–20	8–16	8
Stabilisers/emulsifier	0.2–1.0	0.2–1.0	2.4
% Overrun	50–60	70–80	90

Adapted from Anon. (1977a, c), Mitten (1977), Collins (1977) and Bradley and Winder (1977); for comparison refer to Olsen (1990a, b), Williams (1990/91), Rothwell (1993) and Anon. (1996).

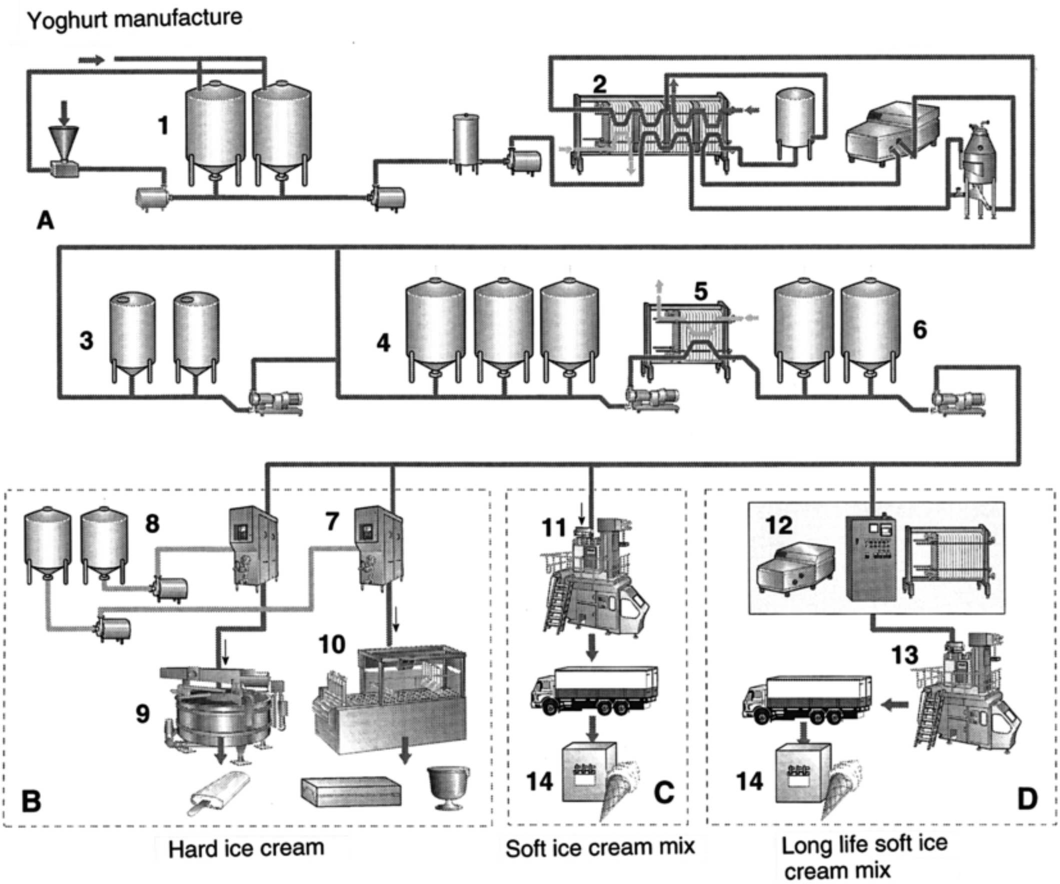

Fig. 5.17 Simplified flowchart for the production of frozen yoghurt: 1, mixing tanks; 2, pasteuriser; 3, bulk starter tanks; 4, incubation tanks; 5, cooler; 6, buffer tanks; 7, ice cream freezer; 8, aroma tanks; 9, bar freezer; 10, cup/cone filler; 11, packaging; 12, UHT treatment; 13, aseptic packaging; 14, soft-ice machine at the retailer

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(e.g. sugar and/or corn syrup) of the fruit base by lactose-hydrolysed whey (Aries, 1977, 1978) (e) Mousse yoghurt without sugar cannot be stored at <0°C, since whey syneresis can occur upon thawing and a partial collapse of the foam occurs.

The chemical compositions of some commercial frozen yoghurts in the U.S. market are shown in Table 5.10. The data illustrate a wide variation in the milk components used. Meyer (1989) provided a comprehensive and detailed ingredient comparison of frozen yoghurts marketed in the U.S.A. The fat content in the mix can affect the quality of frozen yoghurt. Venkateshaiah *et al.* (1994, 1996) reported that a fat level of up to 5 g 100 g^{-1} produced the most acceptable yoghurt, while in Egypt, 10 g fat 100 g^{-1} was recommended (Gooda *et al.*, 1993; Salem *et al.*, 1994a, b); the overrun is increased by increasing the fat content (Chen *et al.*, 1984). Thus, during the preparation of the mix base, a number of ingredients will be used besides the yoghurt and it is essential that the fat and SNF contents are calculated properly to achieve a balanced mix. The algebraic method for calculation is recommended, espe-

Table 5.10 Range of composition (g 100 g^{-1}) of commercial frozen yoghurts sold in the U.S. market

Flavour	Fat	Protein	Ash	Total solids	pH
Vanilla	1.8–5.9	3.5–3.8	0.7–1.0	28.8–34.2	6.37–7.10
Chocolate	3.2–5.7	2.9–4.2	0.9–1.1	31.1–37.6	6.36–7.10
Strawberry	1.7–5.3	1.6–3.2	0.8–1.1	31.2–37.6	4.37–5.70

Data compiled from Tieszen and Baer (1989).

cially when considering the economics of the operation and the quality of the end product. Hypothetical examples have been reported by Hyde and Rothwell (1973) and Marshall and Arbuckle (1996) for the preparation of ice cream mixes and these examples could also be applicable for frozen yoghurt (see also Appendix IX).

As mentioned elsewhere, American consumers prefer frozen yoghurts with a high pH (Speck and Hansen, 1983; Guinard *et al.*, 1994), whilst Gooda *et al.* (1993) concluded that, while low pH mixes improve the overrun of frozen yoghurt, the products gain slightly lower organoleptic scores after 60 day storage than similar products frozen at pH 5.

The milk SNF of the milk base can be adjusted using different ingredients, such as a 50:50 slurry prepared from soyabean and skimmed milk or buttermilk (Rajasekaran and Rajor, 1989), UF of milk and addition of hydrolysed WPC (Maric *et al.*, 1990; Opdahl, 1990; Opdahl and Baer, 1991), skimmed milk, SMP, yoghurt, cream or vegetable oils and sucrose or maltodextrin (Fuisz, 1993; Malone and Sage, 1993, 1994) and condensed cottage cheese whey (Baig and Prasad, 1996a, b).

The combination of fat (10 g 100 g^{-1}) and starter culture (3%) was highly recommended by Salem *et al.* (1994a, b) for the production of frozen yoghurt. However, the survival of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* in frozen yoghurt is of great importance in order to maintain the therapeutic image of the product. Bielecka *et al.* (1982, 1988) reported no inactivation of the starter organisms in frozen yoghurt after 10 months storage at –25°C, and Stenby (1993) reiterated the importance of using special cultures for frozen yoghurt. The viability of the starter culture in frozen yoghurt has been studied by many researchers (Miles and Leeder, 1981; Mashayekh and Brown, 1992; Brown *et al.*, 1991b; Whithead *et al.*, 1993; Childs, 1994; Frison and Agostini, 1994; Thompson and Mistry, 1994; Hong *et al.*, 1996; Andreini, 1997), and observed differences in the counts could be attributed to: (a) the base mix not being properly fermented, (b) the base mix having been heat treated after fermentation and before freezing, and (c) the sensitivity of the starter culture to freezing. Nevertheless, Mashayekh and Brown (1992) and Thompson and Mistry (1994) have reported some reduction in β-galactosidase acitivity (i.e. to about 70%) in frozen yoghurt and, in extreme cases, very low activity makes promoting the efficacy of frozen yoghurt for lactose maldigestors very difficult (Savaiano, 1994). However, improving the survival of the yoghurt bacteria in the frozen product has been achieved using a microentrapment method (Sheu *et al.*, 1993).

Halambeck *et al.* (1984) reported that the use of pure EPS-producing starter cultures was not suitable for the production of frozen yoghurt, because the polysaccharide material interfered with the aggregation of fat and casein. The defect can be minimised by using a blend of non-EPS and EPS starter organisms (Stenby, 1993; Hong *et al.*, 1996).

Consumer acceptability of flavoured frozen yoghurt varies with country (see Chen *et al.*, 1984; van Beckevoort, 1991; Venkateshaiah *et al.*, 1994), as do the types of container used to package frozen yoghurt; some examples have been reported (Anon., 1990a, 1991c, d, 1992b; Friedman, 1991a; Gorski, 1996).

5.8.3 Related products

As with yoghurt, frozen yoghurt has been made successfully from sheep's milk (Smith, 1989; Martinou-Voulasiki and Zerfiridis, 1990) and from buffalo's milk (Mahran *et al.*, 1996; Taha *et al.*, 1997b). Alternatively, low fat Greek-style or strained yoghurt with added pieces of fruit have been used for the production of frozen yoghurt, but no detailed formulations have been reported (Anon., 1990a).

Low calorie frozen yoghurt can be produced from milk low in total solids or with the use of fat substitutes and artificial sweetners. In the former approach, a 70 kcal $100\,g^{-1}$ frozen yoghurt was made by reconstituting SMP to $16\,g\,TS\,100\,g^{-1}$ and, after fermentation, adding carboxymethylcellulose ($0.05\,g\,100\,g^{-1}$) and gelatin ($0.2\,g\,100\,g^{-1}$), homogenising and then freezing (Therrien *et al.*, 1982). Elsewhere, frozen yoghurt has been prepared from skimmed milk, a blend of artificial sweetners with aspartame, non-metabolisable bulking agents, β-galactosidase to hydrolyse the lactose, sucrose polyesters to replace the milk or dietary fat and yoghurt starter cultures to ferment the mix before freezing (Wolkstein, 1986); however, the sucrose polyester could be replaced by starch-based fat substitutes (Steinsholt and Bjørke, 1995; see also Anon., 1995b).

Developments in soft-serve formulations of frozen yoghurt and products "spoonable" at domestic freezer temperatures have been reported by Morley (1984) and Andreasen (1990). Collier and Cardwell (1988) made a similar product by blending yoghurt with ice milk mix (e.g. at a ratio of 40:60) and 8% grape puree (*Vitis rotundifolia*) before freezing; sensory evaluation studies indicated consumer acceptability of these types of fruit flavoured frozen yoghurt. Powder preparations for the manufacture of soft-serve frozen yoghurt have been reported in different countries (Devshony, 1987; Huber and Rowley, 1988; Anon., 1991a, 1992a; Spano, 1995).

Frozen yoghurt has also been proven to be an acceptable vehicle for incorporation of bifibobacteria and *L. acidophilus* into the human diet (McBean, 1990; Morel, 1990). *B. bifidum* and *L. acidophilus* survived well in high pH frozen yoghurt with an average count of each of $3.6 \times 10^6\,cfu\,ml^{-1}$ after 8 weeks' storage at –29°C (Laroia and Martin; 1991; see also Otero *et al.*, 1997), and a similar observation was reported by Modler and Villa-Garcia (1993) for *Bifidobacterium longum*. The same microflora was used in ice cream making and, after storage for 16 weeks at –20°C, the count of each organism was about $1.0 \times 10^7\,cfu\,ml^{-1}$ (Christiansen *et al.*, 1996). However, a slight drop in the count was anticipated before and after freezing due to the incorporation of air at the whipping stage and freezing. Other workers observed no survival of *B. bifidum* in low pH 3.9–4.6 ice cream mixes (Tamime *et al.*, 1995a). Recently, zabady was made by replacing 33% and 50% of the yoghurt starter culture with *B. bifidum* DI or BB_{12}, respectively, during the manufacture of the base from which frozen zabady was made (Kebary, 1996); the numbers of bifidobacteria that survived after 5 weeks' storage averaged $10^7\,cfu\,ml^{-1}$. Arany *et al.* (1995) have reported that, using a roll-tube repair-detection procedure, recovery of cells of bifidobacteria from frozen yoghurt was significantly ($P < 0.01$) better than with the

pour plate method. However, it could be argued that damaged cells are unlikely to survive passage through the digestive tract and hence pour plate counts could provide a more realistic picture.

Hong *et al.* (1996) evaluated three different commercially available bio-cultures (ABT, ABY-2 and AC-180) for their effect on the texture and flavour of frozen yoghurt and they reported that the highest readings for hardness, cohesiveness and elasticity were for the product made with the ABT culture, and that the sensory evaluation scores did not differ significantly between the frozen yoghurts made with the three cultures. An improved nutritional value for "Bellevue" frozen yoghurt is suggested by the use of vegetable oils rather than milk fat along with bifidobacteria and *Lactobacillus* species (Kawano, 1985; see also Taha *et al.*, 1997b), whilst a soft-serve frozen yoghurt that is fat-free and cholesterol-free and has no added sugar has been described (Anon., 1991b).

5.9 Dried yoghurt

5.9.1 Introduction

The primary objective of manufacturing yoghurt in powder form is to store the product in a stable and readily utilisable state. Traditionally, natural/plain yoghurt, which is low in fat, is concentrated, shaped into flat rolls and sun dried (see Kurmann *et al.*, 1992). The dried yoghurt is normally utilised by the desert dwellers in the preparation of food dishes, soups or even consumed like biscuits with tea. However, the first commercial attempts to produce dried yoghurt were aimed at the do-it-yourself consumer market and the reconstituted yoghurt lacked a high viable cell count of starter culture organisms, as well as the pleasant taste, firm body/texture and the attractive appearance of ordinary yoghurt. However, there has been a considerable effort made to improve the quality of dried yoghurt and in general the powder forms are now divided into two different types. In the first type, the reconstituted yoghurt is incubated for a few hours to allow the coagulation process to take place, while in the second type the gel is formed within a very short period of time – so-called instant yoghurt. Neither of these products has gained consumer acceptability because the reconstituted product does not resemble fresh yoghurt. Nevertheless, yoghurt powder can be easily used to prepare a beverage drink. A wide range of patents have been filed in many countries (Ferguson, 1963; Chamay, 1967; Simon and Devallerie, 1968; Anon., 1973a, b; Bohren, 1974; Schur, 1978; Trop, 1980, 1986; Duffy, 1981; Cajicas, 1981a, b, 1990; Rudin, 1984; Tokumaru *et al.*, 1987, 1989; Costanzo and Calcavecchia, 1989; Usacheva *et al.*, 1991, 1992; Kunizhev *et al.*, 1992; Beutler *et al.*, 1993). It is evident from the method of processing that many additives are used to give the powder a yoghurt-like appearance and taste upon rehydration. Some examples of these additives are sucrose, dextrose, stabilisers (i.e. xanthan gums, starch, locust bean gum, Na-alginate), sequestering agents, calcium coprecipiate, organic acids and acidogen (see also Mazaleva and Gugin, 1966; Vitez, 1968; Charon, 1968; Gavin, 1969; Radaeva *et al.*, 1970; Vitanov *et al.*, 1973; Schober, 1973; Schober and Landwehr, 1973; Blanchaud, 1973a, b). The milk may be fermented with a combination of cultures such as *S. thermophilus* and *L. helveticus* or a yoghurt culture and *L. acidophilus* (Rudin, 1984; Beutler *et al.*, 1993).

5.9.2 Processing methods

Traditional products such madeer, oggtt and plain kishk (see Section 5.9.3) are produced by Bedouins in some Middle Eastern countries. Milk from different species of mammals has been used for the production of these products. Normally, skimmed or buttermilk from churned fermented milk is concentrated, shaped into flat rolls and dried in the sun (Al-Mashhadi *et al.*, 1987; Al-Ruqaie *et al.*, 1987; Al-Mohizea *et al.*, 1988). However, Al-Raquaie and El-Nakhal (1987) have produced successfully an acceptable tamar oggtt from cultured skimmed milk and chopped dates (i.e. Tamar in Arabic). Evidence of the production of dried yoghurt can be found from western Asia to Turkestan where the product is called churpi or zurpi, in Nepal chura, in Turkey kurut, in Tibet tschurra, in the former U.S.S.R. katyk and in Algeria klila (Tamime and O'Connor, 1995).

Basically there are two methods of drying that could be employed commercially for the manufacture of dried yoghurt (spray-drying or freeze-drying) and although the latter method of drying would seem the more attractive – the temperature of drying (20–35°C) is much lower than with spray drying (55–60°C) so ultimately causing the least damage to the milk constituents, and/or loss of flavour – it is far too expensive to be considered on a commercial scale. However, another drying method known as air-diffusion (dispersion) drying has been used to dehydrate dahi, and the dried product had properties similar to a freeze-dried one, but with improved reconstitutability (Baisya and Bose, 1974). In a separate study, they reported that the reconstitution properties of dried dahi were improved in the presence of lecithin and corn starch (Baisya and Bose, 1975; Baisya *et al.*, 1978). Rathi *et al.* (1990) freeze dried dahi at –20°C for 12 hour, and the reconstituted product received slightly lower sensory scores, but much lower curd tension and viscosity measurements than a fresh product. The poor rheological properties of the reconstituted dahi were due to the destruction of the gel structure during the drying process. However, a process for the manufacture of dried yoghurt with a predetermined geometrical shape was reported by Costanzo and Calcavecchia (1989) who recommended freeze drying at –30 to –40°C. However, Sharma *et al.* (1992a) and Sharma and Arora (1993) observed that increasing the milk solids in yoghurt to 18.8 g 100 g^{-1} TS resulted in an improved yield of freeze-dried yoghurt from 0.22 to 0.31 kg m^{-2} h^{-1}, and a reduction in the drying time per unit output of 25.8%; a further increase in the milk solids imparted a chalky taste to the dried product.

At present, powdered yoghurt is produced commercially using spray drying, but some precautionary measures should be considered. First, the concentration of yoghurt, before drying, should be carried out at 50–60°C and second, the drying conditions should be moderate to ensure a high viable cell count of *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* in the dried product. In addition, concentrating the yoghurt at higher temperatures increases the scorching onto the surfaces of the evaporator and causes discoloration of the final powder. Masters (1991) and Caric (1994) have provided some specifications for spray – drying buttermilk. The acidified milk was concentrated to 36 g 100 g^{-1} TS at 58°C in an evaporator with a degassing stage and spray dried at 43°C with an integrated fluid bed as a cooler. A scraped surface evaporator might also be used to concentrate the yoghurt before drying.

De and Patel (1989, 1990) produced chakka and shrikhand powders using a spray drier by maintaining the inlet and outlet temperatures at 190 and 95°C, respectively;

the speed of the atomizer was controlled at 25 000 revolutions min^{-1} (RPM). However, for shirkhand powder making, the chakka was mixed with sugar and water and the blend was homogenised before drying.

Both APV and Niro companies are leading drier manufacturers and yoghurt can be dried in a three-stage drying plant. An illustration is shown in Fig. 5.18, and on average, the yoghurt is concentrated to $35\,g\,100\,g^{-1}$ TS, preheated and atomised into the drying chamber with inlet and outlet air temperatures at 160 and 65°C, respectively. The semi-dried yoghurt particles fall down to the bottom of the drying chamber onto an integrated fluid bed drier; such particles form a fluidised layer which is further dried. Later, the powder is transferred to an external fluid bed drier for final drying and cooling. During drying, the product temperature is about 55°C and the powder outlet is at 25°C. Incidentally, the spent drying air from both the drying chamber and external fluid bed drier is drawn through a series of cyclones to recover the fine powder particles (fines) from the air. The fines are fed back to the external bed drier where they are mixed with the bulk of the powder to maximise the yield. Such dried yogurt contains $2\,g\,100\,g^{-1}$ moisture and has a tapped bulk density of $0.5\,g\,cm^{-3}$ (see also Gendrel *et al.*, 1990).

Thus, there are different types of dried yoghurt products (traditional or industrial) available to consumers in different markets and Table 5.11 illustrates some examples. Some of these products contain low quantities of fat because either skimmed milk or the buttermilk from churned fermented milk was used to make the yoghurt. The microbial counts ($cfu\,g^{-1}$) in a commercial dried yoghurt of non-lactic acid bacteria, *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* were as follows: $<1 \times 10^4$, 1×10^3 and 1×10^4, respectively (Anon., 1983b), whilst Pan *et al.* (1995) reported that the count of lactobacilli in dried yoghurt was $7 \times 10^5\,cfu\,g^{-1}$ (see also Rybka and Kailasapthy, 1995; Kim *et al.*, 1997). In the U.K., high and low acid

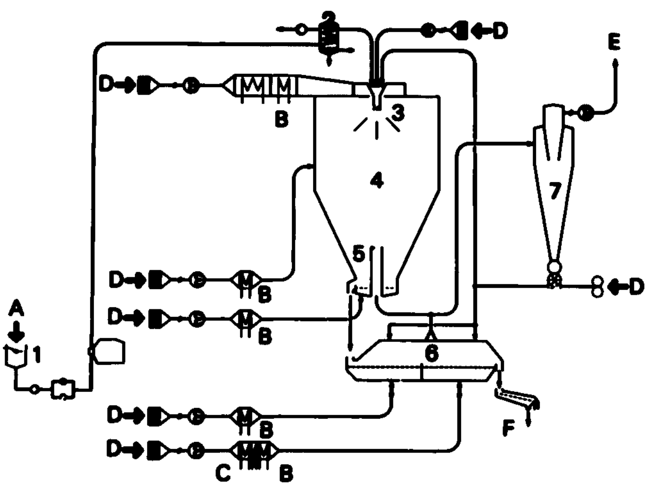

Fig. 5.18 Schematic illustration of a three-stage drying plant for the manufacture of dried yoghurt: A, product inlet; B, steam; C, cooling water; D, air inlet; E, air outlet; F, product outlet; 1, feed tank; 2, preheater; 3, atomizer; 4, spray drying chamber; 5, integrated fluid bed; 6, external fluid bed; 7, cyclone

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Table 5.11 Chemical composition ($g\,100\,g^{-1}$) of different types of dried yoghurt products

Product	Total solids	Protein	Fat	Lactose	Ash
Oggtt					
Sheep (WM)	95.6	31.7	39.3	19.3	5.3
(BM)	91.9	37.3	14.5	32.5	7.6
Cow (WM)	96.3	26.2	25.4	38.7	6.0
(BM)	93.7	31.1	11.0	44.4	7.2
Goat (WM)[a]	92.5	30.4	18.9	37.3	6.5
(WM)	93.1	26.3	28.9	34.8	5.3
Madeer					
Unknown[a]	91.8	36.4	13.4	34.4	7.6
Goat	96.1	35.5	15.3	37.4	7.9
Yoghurt					
Cow (SM)[a]	96.0	33.0	4.0	52.0	7.0
Cow (SM)[a]	96.0	35.0	1.0	54.4	5.6
Kishk (plain)					
Iranian[a]	95.6	54.4	7.9	29.5	3.8

WM, Whole milk; BM, buttermilk; SM, skimmed milk.

[a] Commercial samples.

Data compiled from von Taleban and Renner (1972), Anon. (1983d), Sawaya *et al.* (1984), Al-Mashhadi *et al.* (1987), Al-Ruqai *et al.* (1987), Al-Mohizea *et al.* (1988) and Holland *et al.* (1991).

dried yoghurts are produced to suit different applications within the food industry and the dried yoghurt is packaged in 25 kg multiwall paper sacks with sealed polyethylene liners (Anon., 1987b).

Kim and Bhowmik (1990) reported that the survival rate of the yoghurt organisms was influenced by the processing conditions of the spray drier and they recommended that the product inlet feed temperature be at 30°C, the air inlet and outlet temperatures be at 160 and 60°C, respectively, the atomising air pressure be at 98 kPa and the hot air flow be $0.23\,m^{-3}\,min^{-1}$. The survival rate of *S. thermophilus* was higher than *L. delbrueckii* subsp. *bulgaricus*, but both organisms showed similar survival patterns in freeze-dried yoghurt powder (Kim and Bhowmik, 1990, 1995). However, the fermentation characteristics of the yoghurt microflora and other lactic acid bacteria in an oats-based sour dough and one with enzymatically treated oats influenced the aroma of the products (Marklinder and Lonner, 1992); the intracellular leucine aminopeptidase of *L. delbrueckii* subsp. *bulgaricus* minimised the liberation of bitter peptides (Tchorbanov *et al.*, 1993).

As the formation of the yoghurt gel, after rehydration of some powders, relies entirely on the presence of stabilising agent(s), the yoghurt has a different mouthfeel from the fresh product and this difference could prove to be a limiting factor in terms of acceptability. Alternative outlets for dried yoghurt may include:

- Reconstitution of the powder to 24–26 $g\,100\,g^{-1}$ TS for the production of labneh (see also Kharrazi, 1990; Maroudas, 1992).
- Hill (1974) reported that when adding yoghurt (in liquid form) to dough in the manufacture of baked goods, it could be advantageous to bakers to use the dried form since they are more familiar with handling dry ingredients (see also Fluckiger, 1973). Also, dried yoghurt can be used in confectionery coatings (Main, 1991; Anon., 1991g; Herbertz, 1997).
- The results of field trials on poultry feeding with dried yoghurt, compared with

skimmed milk powder, favoured the former product, due either to an increased availability of nutrients (i.e. metabolisable energy (ME) and gross protein value (GPV)) or to a reduction in the amount of lactose (Simhaee and Keshavarz, 1974).

- Products, such as yoghurt-flavoured wafers and chocolates with yoghurt flavour inners, have appeared on the market in Europe and North America, and the manufacturers of such products may prefer to use dried yoghurt in their processes.
- Dried yoghurt can also be used for the manufacture of yoghurt-flavoured candy (Peterson, 1979), soup preparations (Rezai, 1985), dips (Main, 1991) and oil emulsion products (Milkova and Stamova, 1992).

5.9.3 Kishk and related products

These products are dry forms of yoghurt–cereal (or other additives) mixtures which are made traditionally throughout the region between the eastern Mediterranean and the Indian subcontinent. According to Kurmann *et al.* (1992) and Tamime and O'Connor (1995), many names are applied to dried fermented milk and, depending on the ingredient and/or additivies used, it is possible to classify them as follows:

- Products containing parboiled cracked wheat or flour found in the Arab countries are called kishk, kushuk, keshkeh, kichk, burghul yoghurt, hugut, zhum or kushik, in Greece and Turkey trahana, in Nepal and Tibet chura and in India kadhi (see also Ghosh and Kulkarni, 1990).
- Products containing vegetables, herbs and/or spices are found in Egypt where the product is called kishk siamy, in Greece and Turkey kapestoes, trahanocirv or zamplaricos.
- Products containing other types of cereals (e.g. oats and barley, see Tamime *et al.*, 1997a, b), sorghum (i.e. in Sudan um-kushuk), chick pea, rice or maize (see Dirar, 1993) and pearl millet (Dhankher and Chauhan, 1987a, b).

Milks from different species of mammals (cow, goat, sheep or buffalo) or a mixture of these have been used for the production of kishk. Traditionally, skimmed milk or the buttermilk from churned fermented milk is normally used and whey or milk plus soy-milk has been used in laboratory-made kishk. All these aspects pose problems for the classification of kishk, while the ratio of cereal to fermented milk, which may range between 1:2 and 1:4, affects the quality of the product. Recently, Tamime and O'Connor (1995) have reviewed kishk extensively in terms of its chemical composition (Table 5.12), microbiological quality, nutritional value and methods of manufacture (see also Tzanetakis, 1996).

The main cereal additive (i.e. parboiled cracked wheat) is known by different names such as burghol, bourghoul, burghul or bulgur. The method of preparation could be described as follows. A soft wheat variety is cleaned of stalks, dirt and other cereal grains using a rotary cylindrical machine which is known locally in the Lebanon as ghorbal; it has been illustrated by Tamime and O'Connor (1995). The same machine sizes the wheat kernels into three fractions (i.e. large, small or broken), and the large grains are used to make burghol by steeping the grains in boiling water for 1 hour until soft and then drying in the sun for 24 hours. On the following day, the dried grains are moistened with water (about $20\,g\,100\,g^{-1}$), cracked

Table 5.12 Proximate range of chemical composition ($g\,100\,g^{-1}$) of different types of kishk

Product	Additive	Moisture	Protein	Fat	Carbohydrate	Fibre	Ash
1. Fermented milk							
Commercial	WB[a]	5.5–13.0	8.9–23.5	1.6–16.1	31.0–65.3	0.7–2.5	2.0–9.1
	WB	8.4	17.8	6.4	68.8	9.3	7.0
Laboratory	WB	7.5–9.5	14.5–19.7	–	–	~2.4	4.4–8.7
	WF[b]	6.0–12.5	17.6–19.1	–	~56.3	–	3.6–4.6
	MF	–	18.3	–	–	–	2.2
	CF[b]	5.2	25.8	–	–	–	4.9
	RF[b]	12.4	19.3	–	62.5	–	4.7
	MaF[b]	11.8	17.6	–	60.1	–	4.6
	WB[b,c]	8.7	20.3	6.4	66.7	9.0	[d]
	OB[b,c]	8.2	20.5	9.7	63.0	6.7	[d]
	BB[b,c]	8.4	18.8	6.8	67.9	8.4	[d]
2. Fermented milk +/or soy milk							
	WB	9.1–9.2	16.1–17.2	–	–	–	–
	WB, WF, CF[b]	5.2–9.9	18.3–28.2	–	–	–	3.5–5.3
3. Fermented whey							
	WB	9.7	13.3	–	–	–	–

WB: wheat burghol; WF: wheat flour; MF: malted flour; CF: chick pea flour; MaF: maize flour; OB: oats burghol; BB: barley burghol. Dash indicates no results reported.

[a] Average of 25 commercial Lebanese samples of kishk (Tamime, unpublished data). [b] Computed on dry matter basis. [c] After Tamime *et al*. (1997b). [d] For details refer to Table 5.13.

Data compiled from Hassan and Hussein (1987), Abou-Donia *et al*. (1991) and Tamime and O'Connor (1995).

and dehusked. The burghol is separated from the husk by density fractionation using a mechanical winnowing machine (Tamime *et al*., 1997a). The same machine sizes the burghol into fine or coarse and the latter fraction is used in kishk making. This process can cause the loss of some nutrients from the wheat grain. Tamime *et al*. (1997a) have reported on the losses from burghol made from wheat, oats and barley. In particular, the different parboiled cracked cereals revealed significant differences in the fibre, carbohydrate and mineral content, and these can, in turn, influence the nutritional properties of kishk (see also Oner *et al*. (1993) on the use of soya beans in trahana making).

Details of the many different traditional methods employed for the manufacture of kishk in different countries in the Middle East have been reviewed by Tamime and O'Connor (1995) (see also FAO, 1982, 1990; Farr, 1982; Jandal, 1989, 1994, 1996; Dagher, 1991). Figure 5.19 illustrates the traditional manufacturing stages of kishk

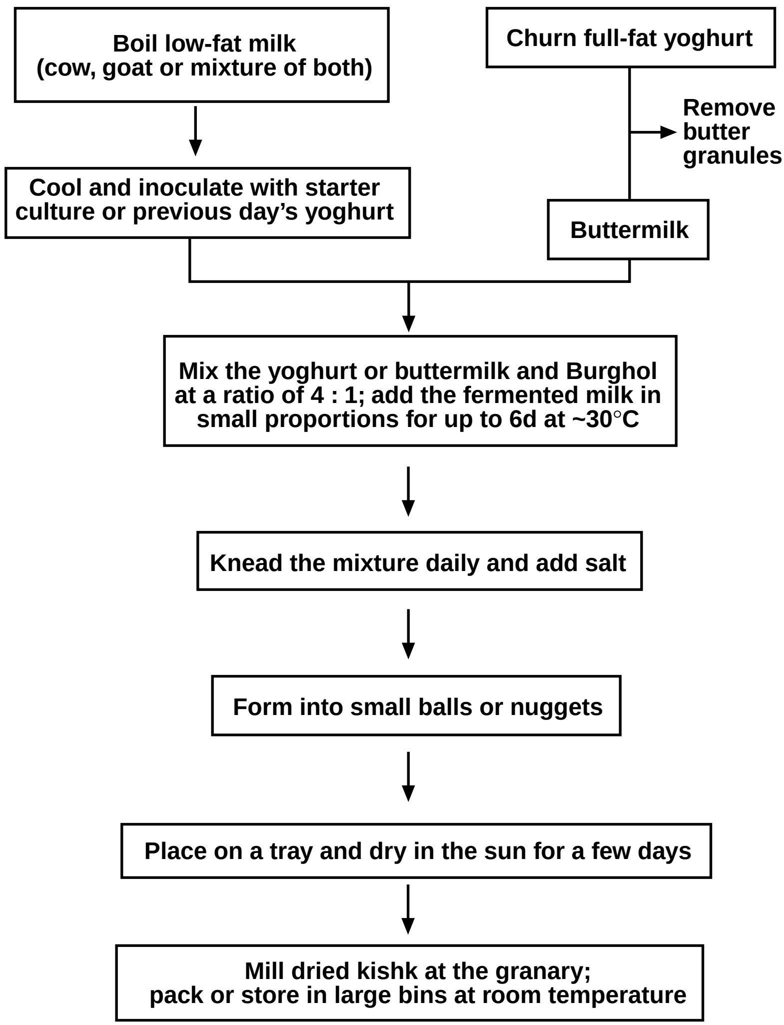

Fig. 5.19 Illustration of the traditional method for the manufacture of Lebanese kishk

in the Lebanon. Ibanoglu *et al.* (1996) used response surface methodology to study the effect of the barrel temperature of a twin screw extruder, the feed rate and the screw speed on starch gelatinisation in trahana making. A regression equation for predicting starch gelatinisation suggested that barrel temperature had the most pronounced effect, followed by feed rate and screw speed (see also Ibanoglu and Ainsworth, 1997).

Garnier (1957), Morcos *et al.* (1973), Robinson (1978), Robinson and Cadena (1978), Cadena and Robinson (1979), Salama *et al.* (1992), Damir *et al.* (1992) and Ibanoglu *et al.* (1995a, b, 1997) have investigated in detail the potential value of kishk for preserving milk protein from spoilage and concluded that the method could prove valuable. The protein content of kishk is high, giving an excellent amino acid content, whose the level is increased due to the metabolic activity of the starter cultures during the fermentation. Kishk contains high concentrations of phenyalanine, threonine, isoleucine, leucine, arginine, valine, tyrosine and lysine, but it has low amounts of tryptophan and sulphur-containing amino acids. The amino acid spectrum of the end product was close to the FAO/WHO (1973, 1985) standard, and only tryptophan and, to a lesser degree, lysine and threonine were at limiting values. The loss of tryptophan could be attributed to the decomposition of the amino acid during the fermentation and sun-drying stages; the tryptophan content of laboratory-made kishk was similar to that suggested by FAO/WHO (1985) (see also Cadena and Robinson, 1979; Sawaya *et al.*, 1984). However, the *in vitro* digestibility of trahana was influenced by the ingredients used including the ratio of fermented milk to cereal used (Ibanoglu *et al.*, 1995a).

Details of the mean concentrations of minerals in kishk have been given by Tamime and O'Connor (1995) and the values are influenced by the type of cereal used. Tamime *et al.* (1997b) profiled the spectrum of the minerals in kishk made with wheat, oats and barley burghol (see Table 5.13). It is evident that the product is a good source of minerals that originate from the milk and cereal, and the wheat burghol including soy milk and chick pea flour are good sources of iron which is deficient in milk.

Kishk is a good source of the B vitamins, but deficient in vitamin C and the fat-

Table 5.13 Mean concentrations (mg 100 g^{-1})[a] of minerals in kishk made from burghol manufactured from wheat, oats and barley

Minerals	Type of kishk		
	Wheat	Oats	Barley
Sodium	1360	1360	1356
Potassium	799	752	753
Phosphorus	552	629	549
Calcium	439	460	425
Magnesium	116	129	107
Copper	0.4	0.3	0.3
Zinc	3.6	3.9	3.2
Iron	21.6	9.3	7.6
Manganese	1.7	3.2	0.9

[a] Data computed on dry matter basis.

After Tamime *et al.* (1997b).

soluble vitamins. The increase in the niacin and riboflavin or provitamin A could be attributed to the activity of the starter culture and addition of tomatoes, respectively (Tamime and O'Connor, 1995). Losses of thiamin (*c.* 30%), but not riboflavin, occurred when the trahana was dried in an oven at 55°C for 48 hour (Ibanoglu *et al.*, 1997).

Kishk (as a dish) is prepared by reconstituting the dried product with water and then simmering the mix gently over a fire. The consistency of this product is rather similar to porridge and it is normally consumed with bread. In some instances, flavouring agents such as chopped onions, tomatoes and/or coriander are added to the gruel mix. Alternatively, kishk is widely used in the Middle East in soup preparations. Although the flavour of kishk or trahana is influenced by the type of lactic acid bacteria used to ferment the milk (Abou-Donia *et al.*, 1991; Lazos *et al.*, 1993), the survival rate may be irrelevant because these products are heated after rehydration.

The unusual flavour and nature of kishk is widely enjoyed among the rural communities in the Middle East, but the introduction of such a mixture to other societies may be rather restricted in terms of appeal and acceptability. However, Cadena and Robinson (1979) conducted an experimental trial in Mexico in which a gruel-type food called atole was replaced by a yoghurt cereal product and the yoghurt-based equivalent was readily accepted by children and mothers, especially when the product was flavoured with strawberry and vanilla extracts. It is safe to assume, therefore, that a flavoured and sweetened kishk could prove to have wide acceptability among communities accustomed to gruel-type foods.

A wide range of basic sensory schemes have been used to evaluate the properties of laboratory-made kishk and related products (see Tamime and O'Connor, 1995), but Muir *et al.* (1995) have developed a sensory vocabulary using a professional panel of eleven assessors to characterise kishk. The descriptors developed were:

- Seven attributes for aroma (overall intensity, creamy/milky, acid/vinegary/sharp, fruity/sweet, cooked, cereal and cardboard).
- Ten attributes for flavour (overall intensity, cream/milky, acid/vinegary/sharp, fruity/sweet, cooked, cereal, cardboard, apple, bitter and salty).
- Five attributes for aftertaste (overall intensity, persistence, acid/vinegary/sharp, cereal and cardboard.
- Five attributes for mouthfeel (viscosity, grainy/floury/chalky texture, sticky/gluey texture, slimy texture and mouth-coating character).

Scottish oatmeal porridges and kishks made from goat's, cow's and mixtures of both milks were evaluated using this sensory scheme and the results could be summarised as follows. First, the oat products were substantially different from the kishk due to the fermented milk component and second, the kishks made from goat's milk were clearly distinguishable from those made with yoghurt of bovine origin.

In another study, Tamime *et al.* (1997b) evaluated kishks made with different cereals and the sensory profiles showed substantial differences between them. Differences in mouthfeel (i.e. grainy, sticky and slimy character) were associated with cereal type. Partial squares regression (PLS2) models derived from the chemical composition of these products were successfully fitted, after cross validation, for grainy, sticky and slimy character. Only the model of grainy character was of predictive value.

The microbiological quality of kishk (commercial and laboratory-made) and related products varied widely which reflects the standards of hygiene during production (see review by Tamime and O'Connor, 1995). Owing to the acidic nature of the product (about 3.8 pH after rehydration), the low moisture content (<10 g 100 g^{-1}) and the presence of salt (*c.* 3 g 100 g^{-1}), kishk should exhibit a high degree of microbiological safety. According to Tamime and O'Connor (1995) and Aytac (1996), the microbiological counts (cfu g^{-1}) of these products were: *Enterococcus faecium* 3.4×10^2, range of total counts $<10 \times 10^3$–2.6×10^7, range of lactic acid bacteria 4.5×10^3–2.2×10^7, and range of yeast and mould 9×10^1–1.4×10^4. The majority of organisms making up the total counts were spore formers belonging to the genus *Bacillus*, and these spores will not be killed when the kishk is cooked. Consequently, if a kishk gruel is prepared, boiled and then allowed to stand at ambient temperature for several hours prior to consumption, toxins generated by *Bacillus cereus*, for example, could cause problems. This could be the reason why the death of two people in Iran, who had clinical symptoms of botulism food poisoning, was associated to the consumption of kishk. Haydarynia (1990) confirmed that *Clostridium botulinum* could survive in laboratory-made kishk and then grow and produce toxins in the gruel but, as the genus is anaerobic, long-term survival in dry kishk is unlikely.

5.10 Bio-yoghurt

The overall nutritive value of yoghurt is well established (see Chapter 9), but special types of yoghurt are often manufactured for dietetic and/or therapeutic purposes and are known as bio-yoghurts. The fact that most strains of *L. delbrueckii* subsp. *bulgaricus* and *S. thermophilus* do not survive in the intestinal tract may be a limiting factor if yoghurt is used for antibiotic therapy and/or any other medicinal purposes. The starter cultures employed in the manufacture of bio-fermented milks including yoghurt-related products are shown in Table 5.14 (Marshall and Tamime, 1997a, b). The main organisms belong to the following genera: *Lactobacillus*, *Bifidobacterium*, *Enterococcus* and *Pediococcus*. The latest nomenclature, classification, physiology and biochemistry of the microfloras used in bio-fermented milks have been reviewed by Sneath *et al.* (1986), Bezkorovainy and Miller-Catchpole (1989), Barlows *et al.* (1992), Wood and Holzapfel (1995), Tamime *et al.* (1995a) and Fuller (1997).

However, although the incorporation of *L. acidophilus* and *Bifidobacterium* species into the yoghurt starter culture may contravene some existing definitions of yoghurt, the resultant milk product is reported to be of excellent therapeutic value. Tamime *et al.* (1995a) and Tamime and Marshall (1997) have reviewed a wide range of products (fermented, dried, frozen confectionery, cheese, baby food, unfermented milk) that are available in different markets. Table 5.15 illustrates some examples of fermented milk products that are available in the European market (Tamime, 1997).

It is evident, however, that knowledge of the potential value of bio-yoghurt in medicinal therapy is limited at the present time, and furthermore that the financial rewards to industry will be dependent on the response and back-up of the medical profession. Nevertheless, since there have been some publications regarding the role of lactic acid bacteria in health and disease (Wood, 1992; Salminen and von Wright,

Table 5.14 Starter cultures that are used during the manufacture of biofermented milks and their principal products

Starter organisms	Principal metabolites	
L. acidophilus	DL	lactate
paracasei subsp. *paracasei*	L(+)	lactate
paracasei biovar *shirota*	L(+)	lactate
rhamnosus	L(+)	lactate
reuteri	DL	lactate, CO_2
B. bifidum		lactate, acetate
adolescentis	L(+)	lactate, acetate
breve	L(+)	lactate, acetate
infantis		lactate, acetate
longum	L(+)	lactate, acetate
lactis		lactate, acetate
E. faecium	L(+)	lactate
faecalis	L(+)	lactate
P. acidilactici	DL	lactate

Data compiled from Devriese and Pot (1995), Marshall and Tamime (1997a, b), Tamime and Marshall (1997) and Tamime (1997).

1993), and it is evident that only those lactic organism(s) that are of human origin and able to proliferate in the intestinal tract of human beings should be considered to be of likely therapeutic benefit.

5.11 Fat-substitutes yoghurt

One method which can be used to manufacture a low fat, light or low calorie yoghurt involves the use of fat substitutes (i.e. materials with the same functional and organoleptic properties as fats but without the calories) to replace the fat in the milk base. Many different types of fat substitute are available on the market and the technically developed fat substitutes are divided into two main types: modified starches or proteins which have good emulsifying or gel properties along with low calorie values; and modified products which contain bonds resistant to digestion, for example, glycerol ethers and complex carbohydrates or fatty acids esters. Thus, it is possible to propose the following approach to the classification of fat substitutes based on their origin or method of processing:

- Modified starches and hydrocolloids including fibre-based products,
- Modified milk, egg and/or soya proteins known as microparticulated proteins,
- Synthetic compounds containing modified ester bonds.

Technical data on these fat substitutes have been reported by Murray (1988), Hendley and Seymour (1988), Lee (1989), Anderson (1990), Keuning (1990), Friedman (1991b), Iyengar and Gross (1991), Altschul (1993), Akoh and Swanson (1994), Miller (1994) and Artz and Hansen (1996). Some patents provide more technical information on fat substitutes (Neilsen *et al.*, 1993; Ohkuma *et al.*, 1993; Rhodes, 1995).

Table 5.16 provides some examples of fat substitutes that are used for fat replacement in yoghurt, butter spreads, sour cream, processed and natural cheeses,

Table 5.15 Commercial and developed bio-fermented milk products

Product	Microflora																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
AB®, Diphilus®, Cultura®, Biomild®, LA7			✓						✓										
Acidophilus-Bifidus yoghurt, Lünebest®	✓	✓	✓						✓+	✓+									
Bioghurt®	✓		✓																
Biokys®			✓						✓								✓		
Olifus®	✓+		✓						✓						✓+				
Progurt®			✓						✓						✓	✓			
BA®, Biobest®, Bifidus yoghurt	✓	✓							✓+	✓+	✓+								
Bifidus milk									✓+	✓+	✓+								
Bifighurt®	✓									✓									
Bifilact®, Bifilakt®								✓					✓						
ABT, Biogarde®	✓		✓						✓										
Bifilus®, Onaka®, Procult 3®, BBA®										✓									
Aktifit®	✓		✓			✓			✓										
BRA® yoghurt			✓	✓							✓								
Pro Viva®, Prima Liv®							✓												
Symbalance®			✓	✓	✓					✓									
Vita®			✓		✓				✓										
Gaio®, Praghurt	✓+	✓																✓	
ABC®, Miru-Miru®			✓		✓							✓+	✓+						
ACT4®	✓		✓		✓				✓										
Yoke®	✓		✓		✓														
Yakult®					✓+	✓+													
Mil-Mil®	✓	✓	✓						✓+			✓+							
Koumiss		✓	✓																✓
Acidophiline			✓											✓					✓
LC1®, Fysig®, Timi Active®			✓																

1, *S. thermophilus*; 2, *L. delbrueckii* subsp. *bulgaricus*; 3, *L. acidophilus*; 4, *L. reuteri*; 5, *L. paracasei* subsp. *paracasei* and biovar *shirota*; 6, *L. rhamnosus*; 7, *Lactobacillus plantarum*; 8, *Lactobacillus* sp.; 9 → 12, *B. bifidum, longum, infantis, breve*, respectively; 13, *Bifidobacterium* sp.; 14 → 16, *L. lactis* subsp. *lactis*, subsp. *cremoris*, biovar *diacetylactis*, respectively; 17, *P. acidilactici*; 18, *Ent. faecium*; 19, kefir yeast.

Data compiled from Tamime and Marshall (1997) and Tamime (1997).

Table 5.16 Classification and some examples of fat substitute products that are used in dairy products

Type/trade name	Technical information		Trade name	Technical information	
	Source	Energy value		Source	Energy value
Modified starches and hydrocolloids					
Gums	Many		Maltrin®	Corn	4 kcal g^{-1}
N-Oil®	Tapioca	3.6 kcal g^{-1}	N-Lite®D	Tapioca	3.8 kcal g^{-1}
Paselli®	Maltodextrin	4 kcal g^{-1}	Litesse™	Polydextrose	1 kcal g^{-1}
Lycadex®	Potato/waxy maize	NR	NatuReal®	Oat	16.8 kcal g^{-1}
Crestar®	Potato	3.8 kcal g^{-1}	Amalean®	Starch	343 cal g^{-1}
Stellar®	Maize	15.4 kcal g^{-1}	Rice® Complete	Rice	16 kJ g^{-1}
Orbitaron®	Maltodextrin	16.7 kJ g^{-1}	Optagrade®	Corn	NR
Tapiocaline®	Tapioca	3.5 kJ g^{-1}	Slendid	Methyl esters of polygalacturonic acid	NR
Modified fibres					
Fibraline®	Inulin	4.2 kJ g^{-1}	Swelite®	Pea	4.2 kJ g^{-1}
Fibrex®	Sugarbeet	2.8 kJ g^{-1}	JustFibre®	Cellulose	0 kJ g^{-1}
Raftaline®	Inulin	4.2 kJ g^{-1}	Oatrim®	Oat	~16 kJ g^{-1}
Sofalite®	Pea	0.5 kcal g^{-1}	Vivacel®	Microcrystalline celluose	0 kJ g^{-1}
Microparticulated protein					
Simplesse®	Milk	16.4 kJ g^{-1}	Trailblazer®		NR
Lita®	Corn	NR	Miprodan®	Milk	NR
Dairy-Lo™	Milk	4 kcal g^{-1}	AMP	Milk	3.9 cal g^{-1}
Danpro®	Soya	11 kJ g^{-1}	Nutrilac®	Milk	~19 kJ g^{-1}
Domovictus®	Milk	15.5 kJ g^{-1}	Globula	Milk	NR
Synthetic compounds					
Olestra®	Sucrose, polyester	NR	Many products	(EPG, TACTA, DUR-Lo and Jojoba oil), but are not widely used in dairy products (see Tamime *et al*., 1994)	

NR, Not reported.

Note: fat-based products such as Delios® and Tropicana® are made from vegetable oil and coconut milk, respectively and have been used in dairy products.

Conversion 1 kcal g^{-1} to 1 kJ g^{-1}, multiply by 4.18.

Data compiled from Huyghebaert (1990), Anon. (1991f, 1994), Blenford (1993) and Tamime *et al.* (1994).

liquid milk and frozen desserts including ice cream (Tamime *et al.*, 1994; Anon., 1994; Phillips and Barbano, 1997). A wide range of scientific papers have been published on fat substitutes, although it is far beyond the remit of this publication to review this topic in detail. Nonetheless, the role of starches as fat substitutes or fat enhancers in yoghurt formulations has been discussed (Doreau 1993, 1994; Anon., 1995c; McGlinchy, 1995), whilst the role of pectin, inulin, rice-based flour, microparticulated whey proteins and insoluble dietary fibre in food and yoghurt making has been reported (LaBarge, 1988; Harrigan and Breene, 1989; Anon., 1990b, 1991e, 1993b; Singer and Dunn, 1990; Kalab, 1990; Riisom, 1991; Singhal *et al.*, 1991; Kratz, 1993; Paquin, *et al.*, 1993; Lieske and Konrad, 1994; Orthoefer *et al.*, 1995; Franck, 1995; Robinson, 1995b; Buchheim and Hoffmann, 1994; Fernandez-Garcia and McGregor, 1997).

Farooq and Haque (1992) produced successfully a low calorie yoghurt using skimmed milk, SMP, modified starch, Aspartame® and sugar esters. The sugar esters, mainly stearates with a hydrophilic–lipophilic balance in the range of 5 to 9 were derived from edible fats and oils. This substitution produced a yoghurt with body, texture and mouthfeel characteristics similar to an equivalent product without sugar esters. In a separate study, low calorie yoghurts were made from reconstituted SMP (about $14\,g\,100\,g^{-1}$ TS) and seven types of starch-based fat substitutes (Litesse™-improved polydextrose, N-Oil®II, Lycadex® 100 and 200 – maltodextrin, Paselli® SA2, and P-Fibre 150 C and 285 F) added at a rate of $1.5\,g\,100\,g^{-1}$, and these were compared with the control made with anhydrous milk fat (AMF) (Barrantes, 1993; Barrantes *et al.*, 1994d). The finished yoghurts had total solids contents that ranged between 14 and $15.6\,g\,100\,g^{-1}$. The lactic acid was mainly produced by *S. thermophilus* and *L. delbrueckii* subsp. *bulgaricus* and the presence of these fat substitutes in milk did not affect their metabolic activity (Barrantes and Tamime, 1992).

The microbiological quality of these low calorie yoghurts was excellent and the coliform and yeast and mould counts were $<10\,cfu\,g^{-1}$ in fresh and stored products; both starter organisms were recovered in high numbers (streptococci $\times 10^8\,cfu\,g^{-1}$ and lactobacilli $\times 10^5\,cfu\,g^{-1}$). All the yoghurts were rated acceptable by the taste panellists, except P-Fibre 150 C and 285 F products which were not favoured when fresh or after storage (Barrantes *et al.*, 1994b). The flavour and aroma scores of the yoghurts were higher after storage, suggesting that the fat substitutes would not affect the quality of yoghurt during storage and distribution (Barrantes *et al.*, 1994b). Also these same yoghurts (with the exception of P-Fibre fat substitutes) were assessed by typical consumers ($n = 182$), but with the products sweetened with $1\,g\,100\,g^{-1}$ sugar and flavoured with strawberries (Barrantes *et al.*, 1993; Ronchetti, 1995). The results suggested that (a) the order of the presentation of the yoghurts was significant ($P < 0.05$) and the products tasted first and last tended to score higher than the other yoghurts, and (b) aspects such as sex, yoghurt consumption habits, age or nationality of the consumer did not significantly influence yoghurt preference; however, overseas consumers (i.e. about 3%) had a higher preference for yoghurts made with AMF and N-Oil®II fat-substitute and lower preference for Lycadex® yoghurts than the U.K. consumers. This latter aspect should be studied separately and with a higher proportion of overseas consumers if the products are to be marketed in foreign countries.

Serum separation and firmness of all these fat substitute yoghurts were very similar with the exception of the product made with P-Fibre 150 C in which the least amount of syneresis was observed during storage (Barrantes *et al.*, 1994c). There was a linear plus quadratic effect (i.e. decrease in serum separation or increase in

firmness) with time. Some statistically significant correlations ($P < 0.05$) were observed when certain variables were combined, protein content, viscosity of the milk, serum separation and firmness). In addition, SEM and TEM studies revealed subtle differences in the microstructure of set-style yoghurts due to the different starch-based fat substitutes used (Tamime *et al.*, 1996). Spikes and hairline structures were evident around the casein micelles in the milk base; they were lightly stained when compared with the caseins. Their detection in the yoghurt was very difficult and they were only seen clearly with the P-Fibre 150 C and 285 F substitutes (Fig. 5.20a); with the other substitutes, spikes could not be detected even when the concentration of the compound was increased to $5\,g\,100\,g^{-1}$. Yoghurt made with Lycadex® 100 was more porous and had slightly larger void spaces filled with milk serum. The use of higher concentration ($5\,g\,100\,g^{-1}$) of fat substitutes increased firmness, but impaired the flavour and mouthfeel of the yoghurts.

In a separate study, Barrantes *et al.* (1994e) reported on the effect of adding protein-based fat substitutes or microparticulated whey proteins (Simplesse® 100 in wet and dry forms) to yoghurts, and compared the end products with yoghurt containing AMF ($1.5\,g\,100\,g^{-1}$). The quality of whey protein-based yoghurts (at a $1.5\,g\,100\,g^{-1}$ level of addition) was high and similar to that of the control samples containing AMF. However, serum separation was higher and firmness lower for yoghurts containing microparticulated whey protein compared with those containing AMF. The differences between yoghurts containing AMF and microparticulated whey protein were most marked when the wet type was incorporated on an equivalent dry matter basis to AMF. The sensory panel identified significant differences ($P < 0.05$) between products containing AMF and microparticulated whey protein only in terms of sour odour and perceived serum separation. The microstructure (i.e. TEM) of these yoghurts revealed that homogenisation of AMF produced fat globules which interacted with milk proteins present in the yoghurt base and thus the fat becomes an integral part of the yoghurt microstructure (Tamime *et al.*, 1995b). Similar integration was observed with the fat substitute, the particles of which (0.1–3 μm in diameter) were found to form part of the casein micelle chains or span adjacent chains (Fig. 5.20b). These chains were found to be somewhat shorter (no statistical assessment was carried out) in the yoghurts made with the fat substitutes in wet or dry forms than in the yoghurt made with AMF.

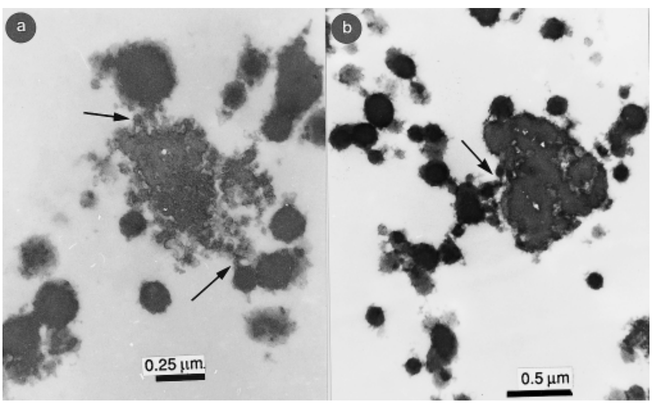

Fig. 5.20 Casein particle chains (TEM) in yoghurt are attached (arrows) to P-fibre 150 C (a) and microparticulated protein particle of Simplesse® fat substitute (b)

5.12 Vegetable oil yoghurt

In developing countries, 'filled' milk products are manufactured from reconstituted skimmed milk powder and the milk fat is replaced by vegetable fats or oils. The use of these indigenous fats and oils is primarily aimed at avoiding the cost of imported fat (i.e. unsalted butter or AMF), while maintaining a wide range of dairy products. Although filled milk products are not supported by the International Dairy Federation, they have been produced for more than 30 years. There is no doubt that these products benefit consumers in developing countries and to satisfy the nutritional requirements of filled milk products, Newstead *et al.* (1979) have recommended the addition of vitamins A and D. Incidentally, dietetic acidophilus milk has been produced in the former U.S.S.R. from skimmed milk fortified with $2\,g\,100\,g^{-1}$ maize oil, whilst in the U.S.A., Metzger (1962b) has patented a process for the manufacture of yoghurt containing unsaturated fat or vegetable oils.

Awareness of consumers in many countries with regard to the dietary aspects of food in relation to cardiovascular disease has increased over the past few decades and the general consensus among the medical profession is that an increased intake of unsaturated fats or oils would be welcome; hence vegetable oil yoghurt may provide an alternative product for consumers. Little data are available on fermented milks made with vegetable oils, but the development of two vegetable fats which can be used in filled yoghurt has been reported (Anon., 1985a). Mouniqua (1986) has patented a base comprising 93% fermented milk (i.e. made using a starter culture of *L. delbrueckii* subsp. *bulgaricus* and *L. helveticus*), $3\,g\,100\,g^{-1}$ oil (e.g. groundnut, maize or soya) and $3\,g\,100\,g^{-1}$ modified starch for the manufacture of low fat and low energy sauces. Whilst Shamanova *et al.* (1989) developed a special yoghurt containing 2.4 and $0.8\,g\,100\,g^{-1}$ dairy fat and vegetable oil, respectively and the product was declared suitable for 1–6 year old children. A mango flavoured filled bio-yoghurt was made successfully from a milk base (18 g and $4.5\,g\,100\,g^{-1}$ SNF and vegetable oil, respectively), processed and inoculated with a yoghurt starter culture and *B. bifidum* (Asgar and Thompkinson, 1994).

Al-Saleh and Hammad (1992) reported that the sensory properties of yoghurt made by substituting milk fat with maize and sunflower oil were characterised as being inferior when compared with equivalent products made with either cow's or camel's AMF or butter. Similarly, Barrantes *et al.* (1996a) reported that the sensory panel had identified significant differences ($P < 0.05$) between natural flavoured yoghurt containing $1.5\,g\,100\,g^{-1}$ AMF and vegetable oils (olive, maize, groundnut or sunflower) in terms of perceived whey separation and some flavour and aroma attributes (e.g. acidic, oxidised, unclean and aftertaste). However, when the same yoghurts were sweetened and flavoured with processed strawberry fruit (Barrantes *et al.*, 1994a), the results of a consumer survey ($n = 80$) suggested that: (a) the yoghurt preference did not appear to be influenced by the amount of yoghurt consumed per week by the consumers (i.e. <3, 4–5 or >5 pots per week) or nationality (Scottish region, elsewhere in the U.K. or from overseas), (b) the yoghurts containing AMF and groundnut oil were rated significantly higher ($P < 0.05$) by females than males, and (c) all age groups (<20, 20–30 and >30 years) rated the AMF yoghurt highest with the sunflower yoghurt lowest; however, only the 20–30 years age group detected any appreciable differences between the other three types of vegetable oil yoghurt.

The stability of the oil emulsion during the manufacture of vegetable oil yoghurt

was reported by Barrantes (1993) and Barrantes *et al.* (1996a). Milk bases (14 g TS 100 g^{-1}) containing 1.5 g 100 g^{-1} of either olive, groundnut, sunflower or corn oil were subjected to homogenisation at 60°C using three different pressures (17.3, 20.7 and 24.1 MPa) and processed in the manner normal for the manufacture of yoghurt. The processed milks, containing no starter cultures, were dispensed into 150 ml plastic cups at 42°C for 3 hours. The oil content of the top and bottom layers was analysed at 0 and 3 hours; any differences in these determinations is indicative of an unstable emulsion. Three hours was chosen because during production it resembles normal yoghurt making, the starter culture would have reduced the pH to a value at which the gel starts to form and, as a consequence, oil droplets would be prevented from rising to the surface. Separation of the milk base was not observed for any homogenisation pressure used and hence no emulsifier was required. Also, no statistically significant difference (variance–ratio test) between the size of AMF or oil globules was observed and the particle sizes in all milk samples were finely dispersed (Barrantes *et al.*, 1996a).

The rheological properties and microstructure of set-type natural yoghurt containing different vegetable oils were reported by Barrantes *et al.* (1996b). They concluded that whey separation was higher and firmness was lower for all the vegetable oil-based yoghurts than for the product containing AMF and microscopy studies (SEM) suggested that the microstructures of all the yoghurts were similar (i.e. porosity of the protein matrices); TEM examinations revealed that both the milk fat and all the vegetable oil globules interacted with the casein micelles and participated in the formation of the gel matrices. Figure 5.21 illustrates these effects. The yoghurts were made with 10 g 100 g^{-1} AMF, cream or vegetable oils (corn, olive, ground nut and sunflower) to show the incidences of membrane formation around the fat/oil globules and its attachment to the casein micelle particles.

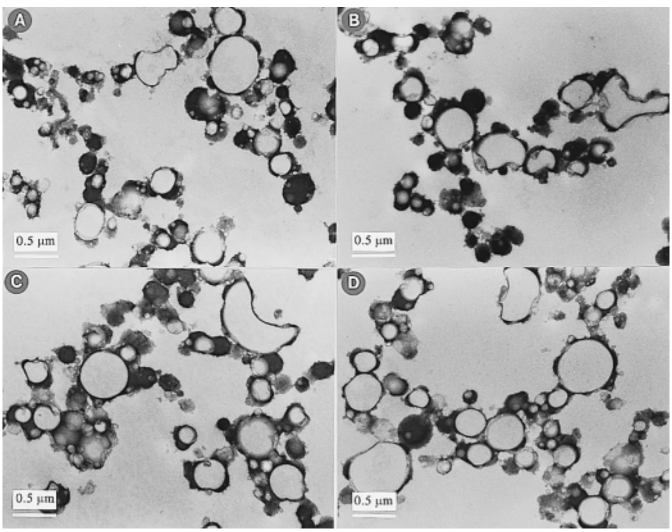

Fig. 5.21 Illustrations of the microstructure (TEM) of yoghurts made with different milk fats or vegetable oils

A, Cream; B, olive oil; C, sunflower oil; D, corn oil.

5.13 Chemically acidified yoghurt

The addition of organic acids (ascorbic, acetic, fumaric, malic, lactic, tartaric, citric, succinic, oxalic and phosphoric) or glucono-δ-lactone (GDL) to milk can result in the formation of a coagulum at pH < 4.6. The end product is referred to as directly or chemically acidified yoghurt, and while it resembles yoghurt in its appearance, delicate gel, body and texture, it lacks the typical aroma, flavour and the therapeutic qualities of cultured yoghurt. The manufacture of this type of yoghurt is included in this section merely for comparison. The principles of this technique are discussed in various patents (Morgan *et al.*, 1970; Edwards, 1976; Igoe, 1979b; Takahata, 1980; Kulkarni *et al.*, 1980; Manabe and Miyake, 1985; Budolfsen and Nielsen, 1994) and details of the kinetics of colloidal aggregation of milk using GDL have been given by Banon and Hardy (1991, 1992).

The parameters selected for the production of directly acidified milk desserts were reported by Schwab (1996) and the milk base ($g\,100\,g^{-1}$) consisted of protein 4, fat 3.4, and sugar 8. However, acidification with lactic rather than citric acid was recommended and this process provides scope for continuous production (see also Hammelehle *et al.*, 1997). The use of calcium gluconate (i.e. as a means of enhancing the calcium content of cultured yoghurt) affected the gel firmness and syneresis of the product (Flinger *et al.*, 1988). However, Akbulut and Kinik (1991) recommended the use of $1\,g\,100\,g^{-1}$ GDL in conventional yoghurt production to shorten the incubation period by 45% and give increased gel strength (see also Gregurek *et al.*, 1996; El-Etriby *et al.*, 1997). A similar observation was reported by Fly *et al.* (1997). Furthermore, Bayoumi and Madkor (1988) and Bayoumi and Reuter (1989) have reported that the combined use of starter culture and $1\,g\,100\,g^{-1}$ GDL in yoghurt making improved the organoleptic properties of the product and a good quality yoghurt could be made from non-homogenised milk.

In a recent study, Vlahopoulou and Bell (1995) compared the gelation processes of fermented milks using EPS and non-EPS starter cultures and GDL acidification of cow's and goat's milk, and they concluded that fermented cow's milk produced a gel with about half the firmness of the equivalent GDL gel, the gel of goat's milk yoghurt was 8 to 10 times than that of the GDL product and the EPS cultures formed weaker gels in both types of milk base than the equivalent non-EPS cultures and GDL.

5.14 Soy-milk yoghurt

Owing to the worldwide shortage of food, attempts have been made to find alternative sources of protein, particularly for the developing countries where malnutrition exists. Since soybeans are plentiful, relatively inexpensive and rich in protein (see Table 5.17), some effort has been devoted to exploiting them for the manufacture of more acceptable and palatable food products. Thus the main objections to soybean products from the consumer are associated with the beany flavour and the phenomenon of flatulence (i.e. production of carbon dioxide, hydrogen and methane by the intestinal flora during the breakdown and/or metabolism of oligosaccharides present in the soybean). It is possible that these problems can, of course, be overcome by various processing techniques and/or fermentations and two current approaches to the production of fermented food are the use of soy-milk for the

Table 5.17 Comparative chemical analysis (g $100\,g^{-1}$) of soy-milk and cow's milk

Component	Milk	
	Soy	Cow
Protein	3.6	3.3
Fat	1.9	3.9
Carbohydrate	2.8	4.7
Ash	0.4	0.7
Water	91.3	87.4

Data compiled from Angeles and Marth (1971) and Table 2.1.

manufacture of a yoghurt-like product and the extension of mammalian milk with soy extracts for the manufacture of yoghurt.

Over time, many researchers in different countries have studied and developed many fermented products, such as soy-milk yoghurt and a bibliography of published work since 1910 has been reported by Aoyagi (1994). Some relevant aspects of soy-milk fermentation have been reported by Mital and Steinkraus (1976, 1979) and Gupta *et al.* (1987); whilst Yamanak *et al*. (1969), Fridman (1976), Emura and Ohba (1989), van Oosten and Verhue (1990) and Karmas and Bachmann (1991) have patented different methods for the preparation of yoghurt from soy-milk.

The production of yoghurt from soy-milk was evaluated by Pinthong *et al.* (1980a–c), who concluded that: (a) using *L. delbrueckii* subsp. *bulgaricus* alone, an acceptable yoghurt-like product can be manufactured from soy-milk, (b) optimum quality of the fermented product was observed at about 1.15% lactic acid, which resulted in the formation of a homogeneous, firm curd without whey separation, and an improved flavour compared with soy-milk, (c) the flavour of fermented soy-milk was directly related to the levels of *n*-pentanal and *n*-hexanal; *S. thermophilus* produces the former compound, while *n*-hexanal is naturally present in soy-milk and (d) the reduction in the level of oligosaccharides was insignificant.

An example of the alternative approach is the fortification of cow's or buffalo's milk with soy extract (basically protein) for the manufacture of zabadi. This introduction of soy-protein into the milk base aimed to alleviate the existing shortage of mammalian milk in Egypt, and when Abou-Donia *et al.* (1980) evaluated the quality of this zabadi they concluded that:

- The level of acidity, total nitrogen and volatile acids increased gradually in both cow's and buffalo's milk, as the level of soy extract was raised from 10 to 50 g $100\,ml^{-1}$.
- In general, the organoleptic assessment of these soy yoghurts was, in terms of body and texture, appearance and acidity, similar to the controls, but the major difference was in the flavour; a score of only 25 points out of 45 was recorded for zabadi with 10 g $100\,ml^{-1}$ soy extract, as against 40 for the control (no soy extract added).
- The use of soy extract concentrations above 10 g $100\,g^{-1}$ imparted a beany flavour which was not accepted by the taste panel.

- The method used for the preparation of the soy extract in this study could not be recommended, since other methods can eliminate the beany flavour altogether.

Khader *et al.* (1983) recommended that defatted soy-milk (i.e. 45%) could be used to replace buffalo's milk for the manufacture of zabadi; whey syneresis decreased dramatically in the product after 24 hours storage at 5°C. However, El-Sayed and El-Sayed (1988) concluded that the addition of soy-milk to buffalo's milk should not exceed 10% because the starter culture counts decreased with increasing soy-milk concentation and the acceptability of zabadi decreased due to the detection of a beany flavour. Choprea and Prasad (1992) observed a reduced rate of acid development in soy-milk fermented with *S. thermophilus* when compared with buffalo's skimmed milk. Yoghurt made from a mixture of buffalo's and soy-milk at a ratio of 65:35 was rated acceptable by a sensory panel; the addition of Na-alginate ($0.2\,g\ 100\,g^{-1}$) improved the texture of the product when compared with the control or with the use of carboxymethyl cellulose.

Dimov *et al.* (1982) produced a dietetic product, which was claimed to be suitable for the prevention of allergic diseases, by mixing yoghurt at 10°C with an equal amount of uncultured soy-milk; this approach could overcome the reduced acid development by starter cultures in soy-milk, and/or their survival during storage. Although the growth of *L. acidophilus, L. delbrueckii* subsp. *bulgaricus* and a yoghurt starter were similar in cow's, UF cow's and soy-milk, and counts did not alter in cow's products during storage, but decreased greatly in fermented soy-milk, the latter products had a distinctive "pulse" off-flavour (Krsev, 1983).

The rate of fortification of cow's milk with soy-milk varies greatly in the reported literature. de Souza *et al.* (1990, 1991) claimed that soy-milk yoghurt containing 10–15% cow's milk was acceptable, especially when flavoured, whilst Caric *et al.* (1983) made yoghurt from milk that was fortified with soy isolate or dried soy-milk; the addition of sugar, coffee and caramel was recommended to mask the soy flavour. Alternatively, a mixture of soy-milk and skimmed milk (i.e. at a ratio of 80:20) plus $1\,g\ 100\,g^{-1}$ sucrose fermented with a mixed culture consisting of *S. thermophilus* and *L. acidophilus* produced a firm yoghurt with no beany flavour (Chopra *et al.*, 1984). However, a mixture of 50:50 was recommended by Miyamoto *et al.* (1983) and the best yoghurt was made with *L. delbrueckii* subsp. *bulgaricus* alone (see also Hardi and Novakovic, 1994; Kinik and Akbulut, 1996; Radwan, 1996). Other reported formulations have been claimed to improve the flavour and consistency of the fermented product. (a) The use of cow's milk fortified with 20% whey protein concentrate (WPC) and 2% soy protein concentrate improved the quality of zabadi (El-Neshawy and El-Shafie, 1988). (b) Soy-milk fortified with 6–8% SMP produced an acceptable yoghurt with good flavour, firm body and smooth texture (El-Gazzar and Hafez, 1992), whilst Patel *et al.* (1989) recommended the use of 2–3% SMP. (c) Soy-milk fortified with caseinates or casein hydrolysate, but not whey protein hydrolysate, and later made into yoghurt was similar to a product made from cow's milk in terms of lactic acid content, key volatile compounds, flavour and texture (Karleskind *et al.*, 1991; Yadav *et al.*, 1994; Granata and Morr, 1996). (d) Soy-milk fortified with cheese whey or whey solids and SMP or dried whey and oat flour were used successfully to produce acceptable yoghurts (Rossi *et al.*, 1984, 1993; Paolielo *et al.*, 1987; Shirai *et al.*, 1992a, b).

Yoghurt made from soy protein contentrates alone had an unacceptable taste and mouthfeel and was yellowish in colour. Such defects could be minimised using

different additives and/or processing methods and some examples include: (a) the addition of glucose or fructose to the milk base (Hasenmaile, 1993) or the use of lactose and citrate (Patel and Gupta, 1982); Buono (1989) and Buono *et al.* (1990c) reported that soy-milk yoghurt was not widely acceptable, (b) enzyme treatment of soy protein concentrate with protease or papain and fortified with 1 g 100 g^{-1} glucose enhanced the growth of *L. acidophilus* and slightly improved the sensory properties of the fermented product (Ko, 1990; Kim *et al.*, 1990), (c) the addition of sucrose, stabilisers, Na-citrate and/or Ca-sulphate helped to improve the flavour and sensory properties of a soy-based product (Paolielo *et al.*, 1987; Shelef *et al.*, 1988; Vargas *et al.*, 1989; Nsofor and Chukwu, 1992; Rossi *et al.*, 1993); however, Cheng *et al.* (1990) observed no improvement in the quality of sogurt made from soy-milk fortified with Ca-acetate, gelatin and lactose, and (d) carbon-treated soy-milk, later fortified with SMP and WPC, produced a product that compared well with yoghurt except for flavour; the treatment did not remove the phenolic compounds present in soy-milk (Lee *et al.*, 1990b; see also Trindade *et al.*, 1998).

The kinetics of carbohydrate utilisation by the yoghurt organisms were studied by Buono *et al.* (1990a, b) who concluded that: (a) the performance of a mixed culture based on a weight : weight ratio was better than that selected on a cell : cell ratio of 1 : 1, and (b) cultures stored in soy-milk ≥168 hour were able to hydrolyse stachyose. de Valdez and de Giori (1993) observed that the presence of *S. thermophilus* in soy-milk cultured with *L. acidophilus* reduced the viability of the lactobacilli in the product. However, Wang *et al.* (1995) reported that the best flavour in soy-milk yoghurt was obtained when the milk base was sweetened with sucrose and later cultured with *L. acidophilus* and *S. thermophilus*; the presence of *B. bifidum* stimulated the growth of both yoghurt organisms in cultured soy-milk (Murti *et al.*, 1993). Shehata *et al.* (1984) studied the growth behaviour of a wide range of lactic acid bacteria in soy-milk (i.e. mesophilic lactococci, the yoghurt organisms, *L. paracasei* subsp. *paracasei* and *L. helveticus*), and they concluded that the growth was improved when soy-milk was heated at 60°C for 15–60 min in the presence of glucose and lactose. These contrasting observations could be influenced by strain(s) variation, and possibly by the type of soy-milk used.

Bacteria cultured in the exudates of cassava and corn reduced the pH of soy-milk at a faster rate than cow's milk and the culture that originated from corn produced the most acceptable yoghurt-like aroma in cultured soy-milk (Nsofor *et al.*, 1992). It may be that different organisms should be used for cultured soy-milk rather than the conventional yoghurt starter cultures in order to minimise the beany taste of soy. Finally, a soy-milk drinking yoghurt was produced from blanched soy bean cotyledons ground with buttermilk (i.e. slurry consisting of soy solids and buttermilk solids in a ratio of 2 : 1 or 1 : 1) and then processed into an acceptable cultured and sweetened product resembling lassi or dahi (Deka *et al.*, 1984; Deka and Rajor, 1988; Rajor, 1990).

5.15 Miscellaneous yoghurt products

A wide range of yoghurt products appear in different markets of the world. While some products may have been commercialised or a limited market has been established, other yoghurt products have been developed in order to generate dietetic/therapeutic yoghurts for medicinal purposes and to provide a wider range of retail products for display in shops or supermarkets than may appeal to special

Table 5.18 Selection of yoghurt-based products for medicinal and product development purposes

Product	References
Cholesterol-free	Metzger (1962b)
Vitamin enriched, Vitana	Metzger (1962a), Anon. (1977d), Primatesta (1981)
Low calorie	Grabs (1979), Munk (1980)
Wheat bran or fibre	Costamanga and Rossi (1980), Anon. (1983c)
Antibiotic therapy, dietetic and pharmaceutical tablets[a]	Anon. (1974, 1977e), Kisza *et al*. (1978), Rossi *et al*. (1978), Kanbe (1987), Tamime and Marshall (1997)
Infant feed	Ivanov *et al*. (1973), Ilyin *et al*. (1982), Rasic *et al*. (1982), Anon. (1983a), Morales de Leon *et al*. (1988), Cavaliere *et al*. (1994b)
Yoghurt for sportsmen	Baltadzhieva *et al*. (1981)
Humanised cultured milk	Kochkova and Spasov (1981)
Guar yoghurt	Robinson and Khan (1978), Khan (1980)
Dietetic soy-milk yoghurt	Dimov *et al*. (1981)
Liqueur or wine	Morris (1983), Anon. (1985b), Kao (1987), Anon. (1990c), Celestino and Dulay (1990)
Sour porridge (uji)	Mbugua *et al*. (1984)
Salad dressing	Main (1991), Suhaj and Krkoskova (1995)
Yoghurt cakes	Yuan *et al*. (1993), Altman and Landis (1995), Saintain (1995)
Pet food	Heinemann and Fedder (1995)
Fermented sausages	Swartz (1982)

[a] Product(s) may contain bio-cultures and yoghurt microflora.

consumers. Some examples are shown in Table 5.18 and some reviews of these products have been published by Mann (1978, 1985c).

A yoghurt product which may have market potential is the mousse, foamed or whipped type-yoghurt. In order to maintain air bubble stability in the foamed product, a combination of stabilisers and emulsifiers are used (Kozhev and Tsonkova, 1986; Zeller, 1986; Dalziel *et al*., 1989). A typical example of an aerated yoghurt formulation (kg) consisted of: yoghurt 5.2, sugar 0.7, cream 3.3 (i.e. double cream about 48 g $100\,g^{-1}$ fat), Hamulsion SPR 0.34 (obtained from G.C. Hahn and dissolved in 1.71 of boiling water at 90°C and added to the mix at 60°C) and fruit (25%). The mix is aerated using a Mondomix machine with an overrun around 65–70% (Tamime, unpublished data).

5.16 Future developments and conclusion

It is evident that some traditional products, for example concentrated/strained yoghurt, have been adapted by technologists for manufacture with mechanised processing equipment and with minimum modification of the quality of the product. Achievements in this area ensure that the products can be commercialised and, at the same time, modified to suit the preferences of consumers in different markets.

Thus it is safe to assume that prior to 1950s yoghurt was virtually unknown outside the Middle East and the Balkan region, but sweetening and the addition of fruits to yoghurt have increased its popularity and acceptability worldwide. It is most likely that some yoghurt-based products may follow these developments, especially products such as dried yoghurt or kishk and related products that may offer nutritional benefits.

5.17 References

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